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A Bibliography of Blue Grouse—1889-1977

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General Technical Report RM-59
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture

Abstract

This bibliography contains 217 references on management and research of blue grouse (*Dendragapus obscurus*). References cover a period from 1889 through 1977. A general subject index is numerically keyed to an alphabetical list of authors.

General Technical Report RM-59 October 1978

A Bibliography of Blue Grouse – 1889-1977

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[1] *Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Research reported here was conducted at the Station's Research Work Unit at the Forestry Sciences Laboratory at Tempe, in cooperation with Arizona State University.*

A Bibliography of Blue Grouse

1889-1977

Kieth E. Severson

The amount of literature on wildlife species and their habitats has accumulated to a point where it is difficult for field biologists and many researchers to maintain reference libraries. Legislation such as the BLM Organic Act, National Forest Management Act, and the Resources Planning Act, however, require land managers to have an intimate up-to-date knowledge of animal requirements. This bibliography will provide sources of information on blue grouse (*Dendragapus obscurus*).

The bibliography should be complete through 1977, although some references may have been inadvertently omitted. Three general classes of information were purposely excluded. The first were life history reports that may interest students and the public, but whose contributions toward research or management information are somewhat limited because of the generalized treatment of information. Only three of these were included because of their excellence: A. C. Bent's "Life Histories of American Gallinaceous Birds" and Paul Johnsgard's "North American Game Birds of Upland and Shoreline" and "Grouse and Quails of North America." Bent's work is one of the earliest and Johnsgard's provides the latest summaries of this type.

Second, references to popular or semipopular periodicals were omitted.

Third, references to Federal aid completion reports are not listed. These are readily available from the Fish and Wildlife Reference Service, Denver Public Library Service Building, 2100 W. Mississippi Ave., Denver, Colorado 80223. Also, because of limited distribution, copies of these reports are difficult to obtain except through the copy services offered by the Fish and Wildlife Reference Service. This is an active file and all persons interested in blue grouse research or management should be encouraged to request an updated list of work done under Federal aid.

A search for blue grouse literature under Federal aid was made in August 1977 and yielded 75 references. Sixteen of these were listed as M.S. theses, journal articles, or Game and Fish Department technical bulletins and are listed in the bibliography: the remaining 59 are project reports and are not listed.

This bibliography contains 217 references dating back to 1889. A general subject index keyed to author is also provided. A number under the subject identifies the article which is listed by author in alphabetical order.

Dr. Fred Zwickel, University of Alberta, and Dr. James Bendell, University of Toronto, provided many of the references listed. Their contributions are gratefully acknowledged.

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This bibliography contains 217 references on management and research of blue grouse. References cover a period from 1889 through 1977. A general subject index is numerically keyed to an alphabetical list of authors.

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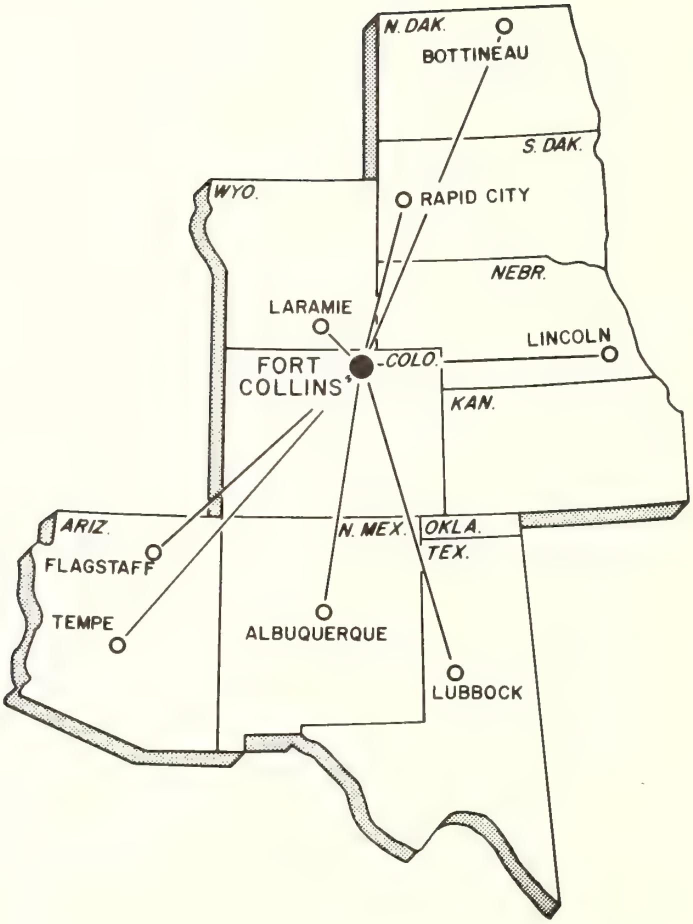
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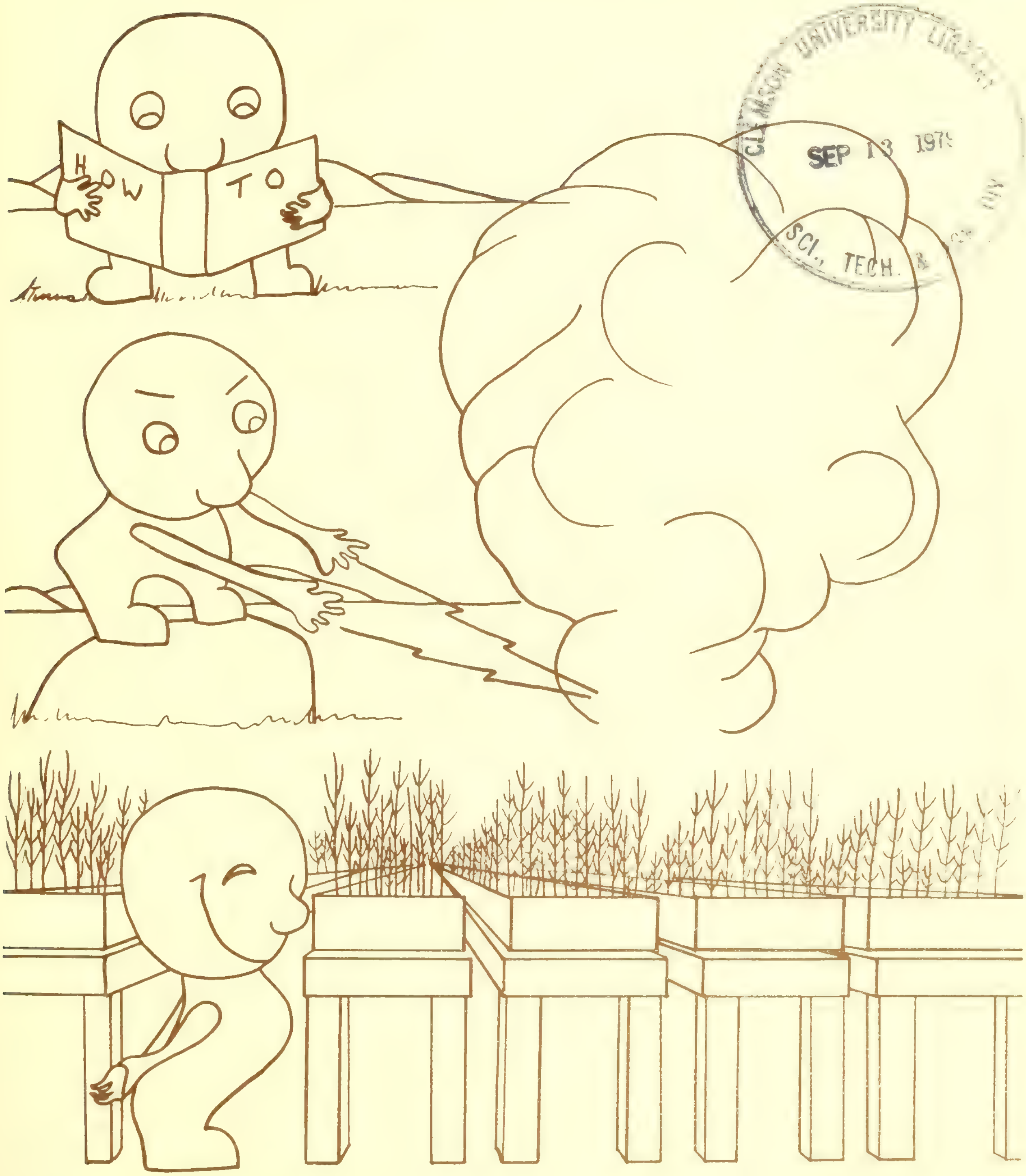
How to Grow Tree Seedlings in Containers in Greenhouses

Richard W. Tinus and Stephen E. McDonald



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General Technical Report RM-60
Rocky Mountain Forest and Range Experiment Station
Forest Service
U.S. Department of Agriculture

Abstract

This guide to development and operation of a greenhouse nursery for container grown forest tree seedlings will help managers decide if a nursery should be built and gives criteria for selecting site, building design and layout, hardware, controls, container, and growing medium. It discusses environmental factors that can be controlled, optimum conditions for growth, and how to achieve them. Growing schedules, greenhouse cultural practices, nursery management, and troubleshooting problems are also discussed.

General Technical Report RM-60 May 1979

How to Grow Tree Seedlings in Containers in Greenhouses

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USDA Forest Service

This publication is jointly sponsored by State and Private Forestry, Rocky Mountain Region, and the Rocky Mountain Forest and Range Experiment Station of the USDA Forest Service.

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[1] *Central headquarters is maintained in Fort Collins, in cooperation with Colorado State University. Tinus is assigned to the Station's Research Work Unit at Bottineau, North Dakota, in cooperation with North Dakota State University.*

Forword and Acknowledgments

A comprehensive manual on containerized tree seedling nurseries and the methods of growing trees in containers has been needed for some time. This manual, begun in June 1975, is presented for use in the field with the understanding that its immediate need will outweigh its flaws. We have consulted with administrators and nurserymen many times in the last few years. This manual attempts to answer the questions that have been asked most often. It is intended to be most useful to beginners, but we hope experienced practitioners will also find it useful.

Many people have contributed to this manual. We have relied heavily on publications and our personal interactions with authorities on the subject. We especially thank the following reviewers for their suggestions and constructive criticisms:

James Arnott
James Barnett
Christopher Goodwin
Phillip Hahn
James Hanover
Thomas Landis
James Lott
Peyton Owston
Glenn Peterson
John Pitcher
Robert Smith
Robert Stevens
Ronald Stewart
Frank Ter Bush

Cover drawing is by Arline Tinus.

We plan to revise the manual in a few years. We hope the readers will advise us of inconsistencies or of new findings in their investigations or experience by contacting us at the Rocky Mountain Forest and Range Experiment Station (USDA Forest Service, Bottineau, N. Dak. 58318) or State and Private Forestry, Rocky Mountain Region, USDA Forest Service, Box 25127, Lakewood, Colo. 80225).

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How to Grow Tree Seedlings in Containers in Greenhouses

Richard W. Tinus and Stephen E. McDonald

SECTION 1.—INTRODUCTION

1.1 Orientation of the Manual

1.2 Information Confidence Levels

SECTION 1.—INTRODUCTION

1.1 Orientation of the Manual

This manual is designed to provide the user with two types of information:

1. A general reference for greenhouse nursery development (sections 2 through 9) with advice on greenhouse development, economics, hardware, and containers. The general advice in the earlier sections should be helpful in making decisions about greenhouse nursery development.
2. A specific reference for growing containerized forest tree seedlings (sections 10 through 21). Explicit directions are provided concerning environmental conditions for optimum growth, nutrition, mechanics, pest control, and troubleshooting. These sections should be most useful to nurserymen.

The manual focuses on greenhouse development and tree growing in the western United States, particularly the interior West, where many new greenhouse nurseries are being started and a great variety of problems are encountered. Much of the information also applies to greenhouse nursery systems anywhere.

This manual is intended to answer most of the questions asked by novices and to help them avoid blunders. It is not an operating manual for any particular nursery, but, by using the principles and guidelines included, a nurseryman can assemble his own (Goodwin 1975, Matthews 1971).

The suggestions and directions in this manual should be used with judgment and discretion. Nothing is as valuable as a nurseryman's personal observation and deduction based on his own experience in his own location.

Throughout this manual, trade names are used only for specificity, brevity, and the convenience of the reader. No endorsement to the exclusion of equally suitable products is implied or intended.

Parts of this manual discuss the use of pesticides. Because of rapid changes in registration and labeling, the reader should check to be sure his proposed use is legal. Remember that pesticides can be harmful to humans, domestic animals, desirable plants, and fish or other wildlife if they are not handled or applied properly. Use all pesticides selectively and carefully, following the directions on the container. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

1.2 Information Confidence Levels

This manual is intended to provide the nurseryman with as much information as possible, but the quality of information about seedling biology varies considerably. The following grading system is used throughout to help the reader decide how much confidence to place in the information:

Level A—This information has been developed in controlled experiments of adequate size and thoroughly tested in production greenhouse situations. It is thought to be complete and accurate.

Level B—This information has been developed in small scale experiments or results from accumulated experience in production greenhouses. It is believed to be valid, but is subject to further testing.

Level C—This information is based on observation, and frequently from isolated cases. It is offered in the view that some knowledge is better than none.

SECTION 2.—DETERMINING PLANTING STOCK NEEDS

There are logical, sequential steps that should be taken before making a final decision to build a tree nursery. Several important facts should be determined at the outset:

1. What species and sizes of trees are wanted?
2. When and where will such trees be planted?
3. How many trees of each species and size will be needed?
4. How long will these needs persist, and how will they change over time?

With these facts determined, the potential nursery developer can analyze the planting stock alternatives available. (Note: Throughout this manual, the acronym "CTS" is used to abbreviate the term "containerized tree seedling.")

SECTION 3.—ALTERNATIVE PLANTING STOCK SOURCES

3.1 Should You Grow Your Own Trees?

3.2 Is a Bare-Root or Container Nursery Wanted?

3.3 Choosing Between Alternatives

SECTION 3.—ALTERNATIVE PLANTING STOCK SOURCES

3.1 Should You Grow Your Own Trees?

Growing your own trees, either in a bare-root (conventional) or CTS facility requires a concerted effort. Much time must be devoted to the project, especially at the outset. Capital investment will be required. In return, there will be good control over the operation and source of planting stock.

There are a number of advantages to **not** growing your own trees. Some of these are the converse of the advantages noted above. Time and capital would be freed for other opportunities. Also, buying planting stock from others passes many of the worries of producing seedlings to the producer.

There are some advantages to procuring some trees from outside sources and growing the rest. Growing only part of the program planting needs affords some security of supply and provides the technical capability needed to produce full program needs, if outside sources are cut off. Growing part of a program's tree needs will also allow good control of production of critical species, or plant materials of unusual value or for special purposes.

3.2 Is a Bare-Root or Container Nursery Wanted?

When a decision is made to start a nursery, should it be a bare-root or container facility? Both types have advantages and disadvantages. In bare-root nurseries, seedlings are grown in exposed seedbeds under specialized farming practices, removed from the soil, and shipped to the planting site with roots bare (fig. 3-1). The principal characteristics of bare-root nurseries are:

1. The trees are grown in soil. Consequently the soil must be suitable for tree-growing (Wilde 1958). Such soil is often difficult to find in a convenient location, and is often expensive.
2. Large amounts of high-quality irrigation water are required (Stoeckler and Jones 1957).
3. Seedlings are exposed to the adverse weather.
4. Much high-quality land is involved along with farm equipment, special nursery implements, an extensive irrigation system, and expensive support buildings.
5. The operation is sensitive to the economies of scale. Once the operation is begun, it is important to function at near capacity levels to keep unit production costs to a minimum.
6. Rate of seedling growth and time of dormancy break are largely controlled by the climate.
7. Little energy is required, compared to greenhouse operations.
8. Seedlings can be compactly packaged and shipped. However, they are perishable and must be kept moist and cool.
9. Natural buffering in the outdoor environment allows seedlings to tolerate mistakes in culture and timing better than in greenhouse nurseries.

The term "containerized tree seedling nursery" refers to those nurseries where the tree seedlings are grown in a medium placed in a container (fig. 3-2). The containers usually are specially designed for this purpose. They can be placed in the open, where the climate is mild, but in more rigorous climates are placed in a greenhouse or under shade fabric where the growing environment is controlled. In this manual, the term "container nursery" usually means "a controlled-environment greenhouse nursery where tree seedlings are cultured in specialized containers" (Tinus 1974a). Container nurseries have a number of common characteristics:

1. They can be constructed on land with low agricultural value (i.e., in many places unsuited to bare root seedling production).
2. While high water quality is an asset in CTS nurseries, it is not as crucial as for a bare-root nursery. Relatively small quantities are required, and quality can be upgraded by filtration and/or addition of chemicals.
3. Greenhouse-grown trees are not exposed to adverse weather, so, production is more reliable.
4. A container facility is less sensitive to the economies of scale than a bare-root nursery. Each greenhouse unit tends to support its own costs, and the nursery is a multiple of such units tailored to demand. No large workforce of diversified skills is required, and most equipment necessary for operation is used all of the time.
5. Container nurseries can use large amounts of energy. This energy is consumed in increasing the speed and reliability of production.

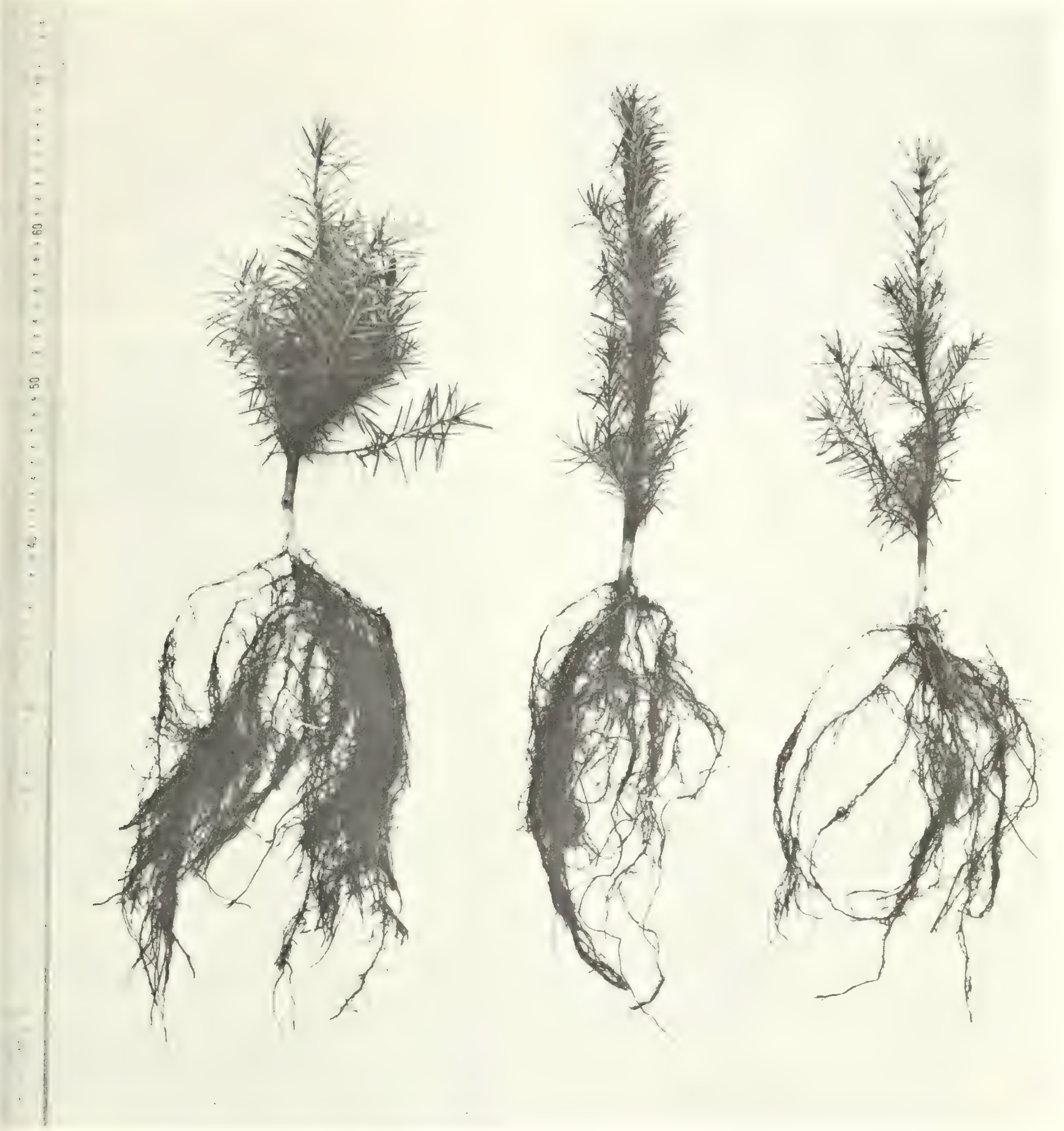

Figure 3-1.—Typical bare root conifer seedlings.

6. Containerized seedlings are bulky to package and ship. However, they are usually less perishable than bare-root seedlings.
7. The controlled environment in a greenhouse increases ability to control diseases and insects, but incidence and rate of spread may be much higher.
8. Container trees can be produced faster than bare-root trees (Stein 1974).

Under some circumstances, a facility combining bare-root and container nursery features might be appropriate. An example might be a nursery site suitable for growing broad-leaved, but not conifer, seedlings. In another case, where the amount of arable land at nursery is insufficient to meet increasing demands by bare-root production, a container facility can be added to supplement production. Perhaps trees from high-value, genetically superior

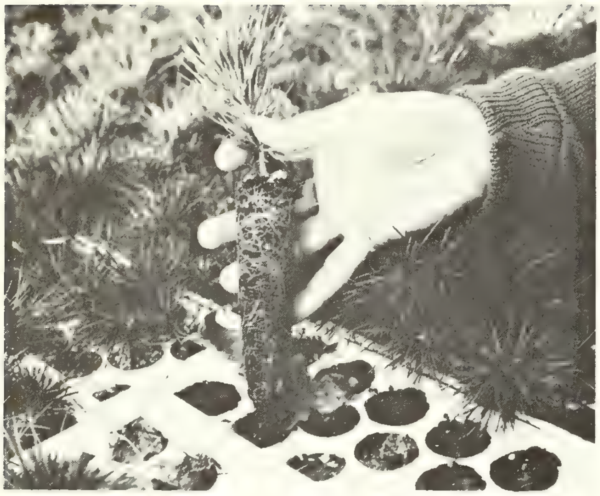

Figure 3-2.—Typical container-grown conifer seedlings.

seed would be raised in a greenhouse where they are protected from the weather, while lesser value stock is reared in outdoor seedbeds. Another case for a combined facility could relate to planting site requirements. Some sites may require containerized seedlings for adequate survival, while on others, bare-root seedlings are most cost effective. Some argument for a combined operation can be made simply on the basis of providing a flexible response to varying production demands, such as rearing container trees to quickly replace a stand destroyed by wildfire.

There are many circumstances where a combination of bare-root and container facilities can be highly complementary, especially where a bare-root facility already exists. Generally, bare-root facilities are most practical for large-scale operations, where providing many seedlings will result in low unit production costs. However, a bare-root nursery must also be on a favorable site, with a reasonably long growing season, to be economical. Container nurseries, however, can produce trees at about the same cost as in small and medium scale bare-root facilities.

3.3 Choosing Between Alternatives

First, is container stock needed for adequate field survival in plantations? If so, the decision is to use a container facility. However, if costs per surviving tree are similar using bare-root or containerized trees, the decision is still open.

Second, is there a suitable bare-root nursery site in the vicinity? Both biological and economic factors (land costs) should be considered. If no such site exists, the decision against a bare-root facility is made.

If both options are still open, the next step is to determine whether the desired production capability can be generated with the available capital. If one option was dropped earlier and insufficient capital is available to develop the desired production level in the other option, the option can be modified to a simpler version (which may be biologically riskier), the level of production reduced, or more capital sought.

Fixed-cost/variable-cost interactions between container and bare-root operations differ as volume of production increases. Projection of production levels, coupled with capital investment and production costs of each option, should indicate the optimum type of operation at different production volumes. A combined container/bare-root operation may be indicated.

Energy source is a key factor in greenhouse operations and should significantly influence the choice between a container or bare-root facility. Fossil fuels are dwindling, becoming more expensive, and in some cases, are interruptable (Besemer 1977 Pimentel 1975, McDonald 1977a). Alternative energy sources, such as waste heat from electrical generating facilities, may be readily available and are adequate for greenhouse heating (Jensen 1977a). Warmer climates cut heating needs. Cheap and reliable energy for greenhouse heating could radically revise an economic analysis of container production. Sole reliance on expensive sources of energy (electricity, propane oil) reduces the attractiveness of the greenhouse option option.

Finally, consider availability of the technica expertise required. No formal training programs fo tree nurserymen are available. However, horticultural departments of various universities train people in greenhouse and ornamental nursery management. As a result, expertise for containe nursery operations may be more readily availabl than corresponding expertise in bare-root nursery operations.

The authors have deliberately kept thes discussions of nursery alternatives brief; before final decision between CTS and bare-root facilities i made, the reader should consult sections 4 and 5.

SECTION 4.—GREENHOUSE DEVELOPMENT

4.1 Requisites for Greenhouse Development

- 4.11 Managerial Commitment and Money
- 4.12 Location
- 4.13 Site Requirements
- 4.14 Energy
- 4.15 Water
- 4.16 Labor Supply
- 4.17 Desirable Site Features
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- 4.21 Economic Data
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SECTION 4.—GREENHOUSE DEVELOPMENT

4.1 Requisites for Greenhouse Development

Greenhouse Nursery development cannot succeed without (1) managerial commitment, (2) money, (3) a location, and (4) labor.

4.11 Managerial Commitment and Money

These two items could be considered synonymous. They are the highest priority requirement for development of a CTS growing operation. Sound preliminary estimates of planting stock needs, investment requirements, and production costs for nursery development will help secure managerial commitment. Initial facility development may be a trial installation for training personnel, demonstrating the techniques, and reassuring management about project feasibility. It also can be a full-blown nursery development, planned as such from the beginning. The rate of development usually is controlled by availability of capital as much as by managerial commitment. Whatever the level, a continuing managerial commitment is necessary to the successful development of an operational CTS nursery.

Greenhouse nursery projects should be carefully planned so the right equipment is purchased and to assure that all capital is invested wisely. Such planning will maximize the likelihood of success, and will reflect well on managers associated with the development.

A word of warning, one of the major pitfalls in CTS nursery development comes from a preoccupation with mechanical and engineering aspects of the work to the detriment of sound economic and biological reasoning. Often the key seasonal operations in a nursery are brief, high volume, high employment, frantic periods of work. In between these periods, the normal level of work involves a relatively few skilled and semiskilled people. The demands on supervisory personnel and the trauma generated during peak work periods can easily make over-mechanization appear plausible, when it is not. The manager and planner must keep in mind that a task lasting a brief time may be accomplished efficiently by intensive application of labor. If the job is continuous or relatively long-lasting, mechanization becomes more feasible. Each case should be judged separately, but the differences between short-run and long-run economics should always be a major consideration in nursery development. To avoid such pitfalls developers of a container nursery should constantly ask these questions:

1. Is this item of hardware required to meet the biological needs of the seedlings?
2. If not, is it wise to buy it to save on labor, maintenance, or other costs?

Answering these two questions, based on the biological needs of the trees and the economics of nursery enterprise, can save thousands of dollars.

4.12 Location

Location is important in CTS nursery development. Room is needed not only for present but also future development. The site should be reasonably level. The character of the soil is not important beyond its bearing strength and suitability for foundations and traffic.

4.13 Site Requirements

The location site **must** have:

1. Energy sources to provide light and heat.
2. Water of adequate quality and quantity.
3. Sufficient available labor.

4.14 Energy

Greenhouse operations often require large amounts of energy. Consequently, the amount and type of energy needed and its availability at the site are key site selection factors. Analysis of the energy aspects of greenhouse location should consider the following factors.

Quantity of energy needed.—Some assessment of energy needs of the proposed greenhouse facility is needed at the outset. This requires an estimate of greenhouse area, construction (heat loss potential), location (weather, elevation), the amount and intensity of artificial light to be used, temperatures to be maintained and their duration, and type of heat source and equipment to be used. In most instances, one or more of these factors, such as location, is assumed before such calculations are made.

Energy source.—Traditionally, greenhouses have been heated with convenient fossil fuels. Presently, such fuels are becoming increasingly expensive, and in some cases, the supply unreliable (McDonald 1977a, Pimentel 1975). Therefore, the choice of energy source is no longer so clear.

1. Fossil Fuels.—Natural gas is the most popular fuel for greenhouse heating (McElroy 1975). It is still reasonably priced, but trends indicate it will be uneconomical for greenhouse use soon (Wiegand 1976).

   Coal and oil are not scarce now, but oil i increasingly expensive and may not be available on short notice. Use of coal as a direct fue source may require expensive antipollutio equipment to make its use environmentally acceptable. Price of liquified petroleum gas (LP likewise has risen, nearly prohibiting its use fo greenhouse heating except as a backup o supplemental heat source (Steinhart 1974).

   Natural gas, LP gas, coal, oil, and electricity can all be transported to the greenhouse site However, natural gas and electricity are no stored at the site. Interruptions in gas and electrical service can be catastrophic. Interruptions in gas service have been rare, but a back-up energy source for gas or electricity should be considered.
2. Electricity.—Some experts predict electricity will be the energy source for the future fo greenhouse heating because it is presently becoming more competitive in price and supply with fossil fuels (Duncan 1975). It is an engineering advantage to place a greenhouse entirely on a single energy source.
3. Solar energy.—Technology is developing rapidly for use of solar energy to heat air or water (Jensen 1976). For climates with enough cloud-free days, this is a viable alternative hea source. However, even the best solar heating units usually will not supply 100% of a structure's heating needs. Prolonged cloudy weather can exhaust stored heat reserves. As a result solar-heated structures require a full capability back-up heat source. They also require a higher initial capital investment than fossil-fueled units. The big advantage of such systems is tha the capitalized "fuel" costs never increase. A careful economic analysis of local feasibility o solar energy use is needed. Solar energy application can be surprisingly economical at high latitudes where the equipment is used for long periods, despite the cold weather.
4. Geothermal energy.—The internal heat of the earth can be tapped where there are natura sources of hot water or steam or by digging wells to inject water into hot rock to heat the water. The hot water or steam is then passed through heat exchangers in the greenhouse There are many oppportunities for using the geothermal resources to heat greenhouses in the western United States (White and Williams 1975). The technology for using naturally occurring sources of hot water and steam is relatively simple, if the water is of usable quality, quantity, and reliability. The water must not be so saturated with dissolved salts that resultant deposits will clog plumbing. The tech-

nology for developing geothermal wells exists, but can be quite expensive, unless circumstances are very favorable (McDonald et al. 1976).

5. Waste heat.—Greenhouses can be heated by waste hot gases or liquids (usually water) that are products of high temperature or energy generating processes (White 1976). Waste fluids other than relatively pure water can be passed through heat exchangers that circulate warmed air or water to greenhouses. Relatively pure hot water can be piped directly to greenhouses. At present, this heat source is probably the most reliable, low cost, and technically feasible energy alternative to direct fossil fuel heating. Nuclear and fossil-fueled steam turbine electrical generating plants are the richest potential sources of such industrial process heat. Numerous manufacturing processes also develop hot gases and liquids from which the greenhouse industry could draw surplus heat. Pulp and paper mills are excellent examples. Canadians have reported direct use of exhaust gases to heat greenhouses (Green et al. 1977).
6. Biogas conversion.—Inflammable gases (methane) can be generated by the fermentation of plant and animal wastes. Conversion equipment is commercially available. The science is better developed in some foreign countries than in the U.S., but our large western feedlots provide unparalleled opportunities for greenhouse heating using this source. With current technology, one cow can provide waste products sufficient to generate enough methane to heat about 250 square feet of greenhouse space in a moderate western U.S. climate.[1] Based on these figures, a 100-cow feedlot operated all year could generate enough biogas to heat a greenhouse complex growing 2 million tree seedlings per year in 8-cubic-inch containers. Since waste disposal at such feedlots is a constant, costly problem, cooperation of the feedlot owners is very likely.
7. Mine-mouth or deep-mine heat.—Many mines are constantly ventilated to provide fresh, cool air to the miners. The air removed is hot and moist. This potential heat source is being tested for greenhouse use in eastern coal regions with excellent prospects for success (Walker et al. 1976, Buxton et al. 1976). There is also a precedent for growing tree seedlings under artificial light deep in a hardrock mine at the Bunker Hill Mining Co., Kellogg, Idaho.

Possible use of non-traditional energy sources.—The potential use of energy sources other than fossil fuels should be a consideration in greenhouse site selection. However, because the technology for utilization of these various types of energy is in different stages of development, and because traditional fuels are still relatively inexpensive, small-scale production of the components for alternative energy systems is often not economical. The Department of Energy (D.O.E.) conducts programs dealing with research and development of such energy sources. For more information contact the D.O.E. Technical Information Center, P.O. Box 62, Oak Ridge, Tenn. 37830.

Heating system design.—Long range planning is especially important in design of greenhouse fuel and heating systems (Love 1975). Most greenhouses in the United States use central heating systems in which the heat of fuel combustion is transferred to water and distributed as steam or hot water (Nelson 1973). These systems are generally more fuel efficient than combustion systems which directly heat the air (Newland 1974).

A few years ago, coal was the accepted fuel. The use of coal decreased because of the increase in its cost per BTU value, delivery problems, mechanical handling problems, clean-up requirements, and discharge of unburned residues into the air. With the rising prices and supply problems of petroleum and natural gas, some return to coal by greenhouse operators probably can be anticipated.

Recently, unit heaters for directly heating the air in greenhouses have gained popularity. Their problem had been poor heat distribution in the greenhouse. This has largely been solved by placing a perforated polyethylene tube on the front of the heater which conveys the warm air the length of the greenhouse, dispersing the heat through the perforations (Walker and Duncan 1975) (figs. 4-1 and 4-2). Popularity of this system comes from its low cost and ease of installation, built-in redundancy (where two or more units are used) and ease of servicing. Such units are usually gas fired.

The type of system (boiler or unit heater) selected depends on economic factors (cost of hardware, ease of installation and maintenance, scale of operation, fuel utilization effectiveness, type and cost of fuel used) and personal preferences. Greenhouse firms selling such structures are experienced at making such recommendations based upon local conditions.

Energy source selection.—Reliable, reasonably priced energy is absolutely vital to CTS nursery development. The price of natural gas in the western United States has risen 200% between 1973 and 1976 (Wiegand 1976). The supply of natural gas for non-domestic uses has been interrupted in recent winters. The medium to long-term prospects for natural gas and fuel oil cost and availability for greenhouse heating is unclear, but two things appear certain:

---

[1] *Personal communication with Lloyd Vic, president, Industrial Systems Engineering, Inc., Albuquerque, N. Mex.*

1. Cost of oil and gas will increase.
2. Availability of natural gas will become less dependable.

Therefore, when oil or gas fuels are used, it may be wise to calculate a short-term benefit large enough to offset the risk attributable to uncertain fuel costs and supply. Ways to do this are:

1. Raise prices of trees produced so the capital expenditure to develop the greenhouse can be rapidly amortized.
2. Build greenhouses that are inexpensive and that have a relatively short projected structural life.
3. Combine these two actions.

Use of a coal-fired boiler to heat a greenhouse complex should assure the nurseryman of a more reliable heat source. Such boilers cost more to purchase and maintain than similar oil or gas-fired models. Also, coal units may require pollution control devices.

The alternatives to fossil fuels can hold a number of advantages. If a long-term arrangement, which stabilizes heating costs, can be found (solar heating, waste heat leasing, etc.), future fuel price increases and/or interruptions might be avoided. Also, such arrangements may provide a constantly improving economic position as fossil fuel costs rise.

The economics of energy source planning for greenhouses are complex and depend largely on the scale of the operation and the perspective of the developer. Modest developments with short-term goals and rapid amortization of capital argue for use of traditional fuels at present. Large developments with long-term capitalization of substantial investments may be better served by using some alternative, nontraditional heat source.

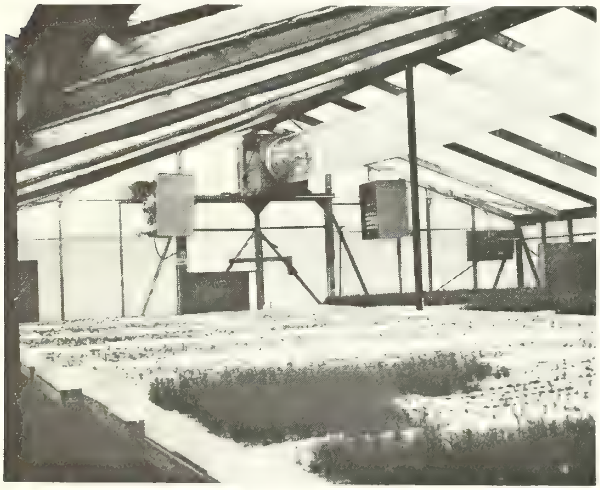

Figure 4-1.—A perforated plastic tube system used for air circulation, heat distribution, and first stages of ventilation.

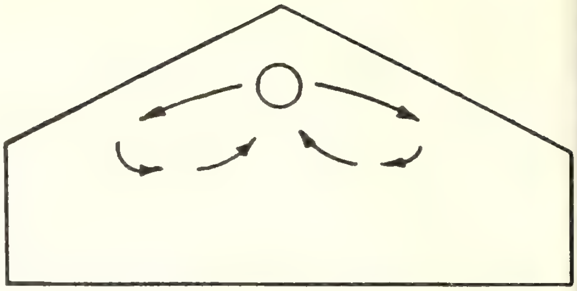

Figure 4-2.—Overhead perforated polyethylene tube.

4.15 Water

The quantity of water required for a container nursery is modest compared to a bare-root nursery. Still, some idea of the amount that will be required is needed for site selection. Approximately 0.4-0.5 gallons per hour per square foot (16-20 l/hr/m^2) of greenhouse area is needed to water 8-inch (20-cm) deep tree seedling containers. This rate of application is great enough to avoid having the foliage wet long enough to unduly encourage fungal development. A change in this rate for different depths of containers should be proportional to the difference in the depth. If a 12-inch (30-cm) deep container is used, the rate would be increased to 0.75 gallons ($12 \div 8 \times 0.5$) per square foot per hour (30 l/hr/m^2). About the same watering capability is required for shadehouse. Rates of use also have to be calculated for the rest of the complex: domestic needs, landscaping needs, cooling water. However, these are normal components of civil engineering calculations and are available from engineering sources. The total flow rate estimate for the installation need not assume that the whole system will be used at the same time. Watering in greenhouses, shadehouses, and lawns can easily be staggered, and the total flow rate requirements of the installation correspondingly reduced (and money saved in installation costs).

Estimates of total annual water needs are often required of prospective water users seeking water rights. In drier climates, for 8-inch (20-cm) deep containers in a greenhouse operated all year, about 100 gallons per square foot (4,070 l/m^2) of greenhouse space will be needed. In more humid climates only about 30-40 gallons per square foot will be needed.[2] Again, a change in container depth will result in a proportional change in the water requirements. Reduction in the time the greenhouse is occupied will result in a directly proportional reduction in water need. Trees in a shadehouse will require equivalent amounts of water for the months the shadehouse is used. An example of calculations to arrive at the necessary figures for water demand follows:

---

[2] *Personal communication with Phillip Hahn, Forestry Research Manager, Georgia Pacific Corp., Eugene, Oreg.*

Given:

1. Other nursery water needs—40 gallons (150 l) per minute at 40 pounds per square inch (2.8 kg/cm^2)
2. 5,000 square feet (464 m^2) greenhouse
3. 7,500 square feet (695 m^2) shadehouse
4. Two crops per year in greenhouse
    (3 months for one in 6-inch (15-cm) deep containers)
    (9 months for the second in 10-inch (25-cm) deep containers)
    (6 months for first crop in shadehouse)
5. Shadehouse water is never on at same time as greenhouse water.
6. Eight-inch (20-cm) deep containers need 100 gallons per square foot per year (4,070 l/m^2/yr)
7. Eight-inch (20-cm) deep containers need 0.5 gallon per hour per square foot (20 l/m^2/hr)

Calculation of water rate needs.—The shadehouse and greenhouse will not be operated at the same time, but have different areas with different containers. Therefore, it must be determined which unit requires the **greater** flow of water.

Greenhouse:

(1) (0.5 gallons per hour per square foot) × (10-inch deep containers) ÷ (8-inch containers) =
(2) (0.5 gallons per hour per square foot) × (1.25) = 0.625 gallons per hour per square foot
(3) (0.625 gallons per hour per square foot) × (5,000 square feet) = 3,125 gallons per hour (11,800 l/hr)

Shadehouse: (10-inch-deep containers will never be in the shadehouse.)

(1) (0.5 gallons per hour per square foot) × 6-inch containers) ÷ (8-inch deep containers)
(2) (0.5 gallons per hour per square foot) × (.75) = 0.375 gallons per hour per square foot.
(3) (0.375 gallons per hour per square foot) × (7,500 square feet) = 2,812 gallons per hour (10,630 l/hr)

The water flow rate needed for the greenhouse is greater with 10-inch (25-cm) containers than the shadehouse with 6-inch (15-cm) deep containers, even though the shadehouse is larger. The total volume per minute demand for the facility is estimated by converting the maximum gallons per hour for the greenhouse into gallons (or liters) per minute and adding the gallons per minute requirement for the rest of the facility (given, from engineer's estimate):

(3,125 gallons per hour) ÷ (60 minutes) = 52 gallons per minute + 40 gallons per minute = 92 gallons per minute or approximately 100 gallons per minute (378 l/min.)

Facilities projected beyond the current development should also be calculated into the rate and total annual needs. Normally, no two greenhouses would be using water at the same time, unless there are many greenhouses.

Total annual water needs calculations.—The greenhouse will be used all year, while the shadehouse is used 6 months a year. Assume fall is rainy. Therefore, 4 months of irrigation is needed at this location. The other uses are estimated by engineers to be 1,000,000 gallons per year (3,800,000 l/yr).

Therefore:

Total annual greenhouse needs:
100 gallons per square foot per year for 8-inch-deep containers
(1) (100 gallons per square foot per year) × (3 months ÷ 12 months) × (6-inch-deep containers ÷ 8-inch-deep containers) =
(2) (100 gallons per square foot per year) × (0.25) × (0.75) = 18.75 gallons per square foot per year.
(3) (100 gallons per square foot per year) × (9 months ÷ 12 months) (10-inch-deep containers ÷ 8-inch-deep containers) =
(4) (100 gallons per square foot per year) × (0.75) × (1.25) = 93.75 gallons per square foot per year.
(5) Adding (2) plus (4) = 18.75 + 93.75 = 112.5 gallons per square foot per year.
(6) (112.5 gallons per square foot per year) × (5,000 square feet) = 562,500 gallons per year (2,126,000 l/year) for the greenhouse.

Total annual shadehouse needs:

(1) (100 gallons per square foot per year) × (4 months) ÷ (12 months) × (6-inch-deep containers) ÷ (8-inch-deep containers) =
(2) (100 gallons per square foot per year) × (0.33) × (0.75) = 24.75 gallons per square foot per year.
(3) (24.75 gallons per square foot per year) × 7,500 square feet) = 185,625 gallons per year for the shadehouse.

Total greenhouse and shadehouse needs are 562,500 + 185,625 = 748,125 gallons per year (2,828,000 l/yr) or about 1 million gallons per year; with the 1 million gallons estimated for other uses, a minimum of 2,000,000 gallons (7,560,000 l) per year would be needed.

Water quality.—Quality of the water at a proposed greenhouse location is an important consideration in the site selection process. The source of the water to be used often has a definite effect on the water quality. Generally, sources fall into one of five categories:

Municipal water (water from wells or surface sources that has been treated to be potable).
Well water.
Irrigation system water; piped, but not potable.
Surface water from ponds, streams, or lakes.
Sewage effluent water.

Water quality is measured by the nature and amount of suspended and dissolved impurities. Suspended matter is material in the water that would eventually settle out, such as sand, silt, organic particles, etc. Inorganic ions and organic compounds dissolved in the water do not settle out. Suspended material can wear, abrade, and block nursery equipment and hardware. Municipal water usually has been filtered to remove particulate matter. This is not always true, however, and should be checked. Depending on the aquifer, well water may contain sand or silt. Sand can be filtered, but complete silt removal is much more difficult. Both sand and silt are abrasive and can quickly wear out water pumps, fertilizer injectors, and some types of sprinkler heads. Surface water sources, in addition to possibly having sand or silt, often will have suspended organic matter such as leaves, insects, seeds, spores, algae, etc. Pathogenic nematodes and fungi could be a problem, especially if the water includes runoff from agricultural land.[3] One way to improve the quality of such water is to create a settling pond that can be treated with chemicals.

The nature of the dissolved matter in a water source is of great importance. Water tests normally made by state health departments usually list the chemical properties of particular water solutions under several headings:

1. Concentration of various ions present in the water.—The list of ions on a standard water test is not all inclusive. Some are known plant nutrients, and some are not. The ionic concentrations may be expressed as milligrams per liter (mg/1) or parts per million (ppm), which, for our purposes, are equivalent.
2. pH.—This is a measure of the relative alkalini or acidity of the water, and is familiar to mo nurserymen.
3. Total dissolved solids.—This figure is the sur mation of all ions in the solution. It sometimes called the "total dissolved salts," ar is related to the osmotic pressure imposed b the soil water solution. If the salt concentratic of the soil water solution around a tree's roots too high, the tree will not be able to extra water from the soil. Of course serious grow inhibition comes long before this extreme poi is reached. "Total Dissolved Solids" inform tion helps determine suitability of the water f use as irrigation water in a greenhouse.
4. Total alkalinity.—This figure expresses tl amount of some compound (often CaCO equivalent to the amount of alkalinity in water solution.
5. Total hardness ($CaCO_3$).—This is the total all divalent ions in the water that would cause precipitate when combined with sodium palm tate (soap). These ions are usually calcium ar magnesium, but also include other heav metallic ions. The figure is of little use nurserymen as are the general terms "hardnes and "softness" when related to water quality.
6. Conductivity.—This is another measure total dissolved ions in the water expressed ease of passage of electrical current through tl solution. The figure is usually expressed millimhos per square centimeter (mmhos/cm^2 read from an electrical conductivity meter. Th higher the reading, the higher the salt conce tration in the solution.

Preliminary evaluations of water quality.—Durin the first visit to a proposed site, some basic ob servations will give the investigator important clue to the water quality. The amount of deposits c carbonates on sprinklers, faucets, sinks, etc., is good indicator of the amount of calcium and mag nesium bicarbonates dissolved in the water supply Another indication is that the water will taste heav and flat. For a third test, note the effort and amour of soap required to work up a "lather" and how lon the suds, if any, persist on the surface of the water. little soap or effort is required for a lather and suc persist on the water's surface there is little calcium c magnesium in the water. The presence of "scum" o the water can indicate calcium or magnesium bicar bonates. If the soap is difficult to rinse off, there ma be considerable sodium in the water.

If the water tastes salty, sodium chloride probably present. This should alert the developer t potential problems with the osmotic limit for dis solved solids or chloride toxicity.

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[3] *Personal communication with Dr. Glenn Peterson, Project Leader, Rocky Mountain Forest and Range Experiment Station, Lincoln, Neb.*

Brown or orange-brown stains where water has run repeatedly usually indicate iron in the water. This probably has no serious negative implications, but the water could stain the greenhouse cover eventually.

A sulphur or "rotten egg" taste or smell indicates the presence of sulphides in the water.

When water containing bicarbonates is heated or evaporated, carbonates are deposited. This is generally not a problem, since it is recommended that all water used in irrigation be acidified (section 13). Acid solutions keep the calcium and magnesium bicarbonates in solution and alleviate most carbonate deposition. However, the concentration of bicarbonates can have serious consequences when unacidified water containing these ions is used for boiler system water or on cooling pads. When supplied with water test data, heating and cooling system engineers can determine if water will have to be treated for these uses.

Indications of high concentrations of calcium or magnesium bicarbonates or iron sulphates should not seriously affect greenhouse nursery site selection unless another equal or better site is available. However, any indication of relatively large quantities of sodium chloride, or heavy metals in the water should cause serious concern.

Evaluating a chemical water test.—If the site looks promising, a chemical water test should be made. Chemical components of water at a single location can vary from season to season, especially with surface water sources. Similarly, the chemical nature of well water can vary considerably in a locality. Conclusions drawn from a single sample or from water from a well adjacent to the planned development, should be considered tentative and rechecked at different times of the year. The actual water applied to the crop should be tested if possible. Routine water chemical analyses do not indicate concentrations of heavy metal ions such as lead, chromium, cadmium and mercury. However, even low concentrations of these ions in water can be toxic to plants. Presence of heavy metal ions in the water source is possible if:

1. There is a history of heavy metal contamination of water in the area.
2. The aquifer the water is coming from is one which bears metal ores.
3. The water is effluent from a sewage treatment plant.

If any of these statements are true, the water should be checked for heavy metal ions and the results analyzed by specialists who can relate the concentrations to tree growth.

Other toxic substances may be found under these conditions:

1. Water draining from swamps or bogs may contain chemical plant growth inhibitors leached from decaying plants. Some plants manufacture inhibitors to reduce competition with other vegetation—black walnut is the common example. When such plants decay in swamps and bogs, these inhibitors can be dissolved in the water.
2. Water from geothermal sites frequently contains sulphide or sulphite ions which are harmful to plant growth.
3. Surface water sources can be contaminated with complex organic compounds used in manufacturing or pest control. Possible sources of such contaminants should be examined before the greenhouse site is selected.

Below are water quality guidelines to use when choosing CTS greenhouse sites. These approximations are for preliminary site evaluation only.

1. Ion toxicity.—Nearly any ion required by plants, and many not demonstrated to be required, can be toxic to plants when supplied in excess. Table 4-1 lists nutrient ion concentrations that are suitable for plant growth and levels that should not be exceeded in the water supply (Hoagland and Arnon 1938). (Hoagland's solution may not provide optimum nutrition for trees but is useful for lack of a better guideline. This solution generally provides an osmotic tension of about 1.5 bars).
2. Dissolved solids.—The growth of most trees is retarded when the salt content of the soil solution exceeds a rather low value (Ayers 1977). Harmful effects of high salt concentration are attributable to effects of certain ions on plant metabolism when they are present in high concentrations and to reduce water absorption because of the high external osmotic

Table 4-1.—Composition (ppm) of Hoagland's solution and maximum ion concentrations allowable in a water source. Maximum concentrations listed may be too high for some species.

Element	Hoagland's solution	Maximum concentration
Nitrogen	210	500
Phosphorus	31	150
Potassium	240	500
Calcium	170	600
Magnesium	48	150
Sulfur	64	500
Iron	4	40
Chlorine	4	40
Manganese	0.5	5
Boron	0.5	5
Zinc	0.05	0.5
Copper	0.02	0.5
Molybdenum	0.01	0.5

pressure. Because the medium in which trees are reared is kept near field capacity (0.3 bars), there is little reason to worry about salt accumulation in the medium, particularly if the conductivity of the leachate from the containers is monitored as recommended in section 13. However, high salt concentrations especially sodium chloride, in irrigation water may damage the tree seedlings or seriously narrow the margin of safety between good tree growth and the osmotic limit. Conifers appear to be unusually susceptible to damage from excess dissolved salts in water (Baxter 1943, Kramer and Kozlowski 1960).

What salt concentrations are reasonable? Comparing the Total Dissolved Solids figure or electrical conductivity (one measure of total dissolved solids) (Section 6.56) from a water test from the proposed source water and the proportions of sodium and potassium ions to calcium and magnesium ions from the same test (Table 4-2), will estimate the desirability of the water (Black 1957, Sutcliffe 1962, Levitt 1972, Richards 1954).

3. "Total alkalinity."—Usually given as $CaCO_3$ equivalent, this figure can be used to calculate the amount of acid necessary to "buffer" the water to a slightly acid condition. Since relatively little water is used for irrigation in greenhouses, this calculation is not important at the preliminary site selection stage, although it is very important in calculation of nutrient solution compositions (section 13) after the water source and site are fixed. For site selection purposes, water giving total alkalinity figures in excess of 600 mg/l $CaCO_3$ should be avoided.

4.16 Labor Supply

A sufficient supply of labor must be available for the size of operation to be installed and that contemplated for the future. The work force needs to be relatively stable, semi-skilled, and capable of rapid expansion for shipping trees or loading greenhouses. The number of employees required depends on the size and complexity of the operation. An average of one laborer for each 120,000 trees and at least one technical supervisor for each 3,000,000 trees may be used as a rule of thumb.[4] Other large consumers c labor in the area should be known, so that areas ca be avoided where seasonal pursuits (fruit harves etc.) may "dry-up" the labor supply when th workers are needed most.

4.17 Desirable Site Features

Sections 4.13, 4.14, 4.15, and 4.16 dealt wit greenhouse location features that are "musts (energy, water, and labor supply). This section dea with site attributes that are desirable, but nc required.

Favorable climate.—A good greenhouse sit should have a warm, dry, sunny climate withou temperature extremes, located at as low an elevatio as possible. These site characteristics will lesse structural and energy requirements for a greenhous Usually, the choice is a compromise between di ferent mixes of characteristics. Climatic and latitu dinal features of a site will affect both the fixed cos and variable costs of greenhouse operation. Fo instance a less expensive structure with smaller fan heater, etc., would reflect the influence of a mil climate. This, in turn, means a lower amortizatio rate to carry over the life of the facility as part of th unit production price. Variable costs in the form c fuel and electricity will be less, if the greenhouse placed at a sunny, mild, low elevation site.

Certain locations should be avoided. Valle bottoms and toes of slopes are cold because of col air drainage. Frost pockets form where downslope a drainage tends to accumulate. Impingement angle c sunlight should also be considered. Amount c sunlight is often a limiting factor in greenhous operations in central and northern states (Dunca 1975). In such areas, greenhouses should have a open southern exposure. Obstructions that interfe with light on its way to the greenhouse must b avoided. As a general rule, the greenhouse should b located at least 2.5 times the height of the obje away from it in either the east, west, or sout direction (A.S.H.R.A.E. 1965).

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[4] *Personal communication with Robert Smith, Nurse Manager, Crown-Zellerbach Corp., Aurora, Oreg.*

Table 4-2.—Desirability of water supply as a function of conductivity or total dissolved solids and Na to Mg + Ca ratio (Richards 1954).

Ratio Na/(Mg + Ca)	Good		Usable but not desirable		Not acceptable	
	(ppm)	(mmhos)	(ppm)	(mmhos)	(ppm)	(mmhos)
< 1:2	< 400	900	1500	3000	2000 +	4000
> 2:1	< 200	250	500	700	600 +	800

Sheltered area.—The greenhouse should be placed where it is sheltered from the wind. Although maximum sunlight should be the first consideration, placing a greenhouse in a sheltered area reduces wind-induced heat losses (Duncan 1975). Pick an area with relatively low air velocities (check weather records) if possible.

Physiography.—The physiography of a greenhouse site should be reasonably level and well drained. The site should be more than large enough to allow for future expansion.

Closeness to market.—The greenhouse should be as close as possible to the market for its production to minimize transportation costs.

Supply and maintenance.—Supply and maintenance services should be available nearby. Proximity to these services will save money time and time again.

Living quarters.—A good greenhouse site will allow a person responsible for its operation to live nearby. If there is not a town nearby, it may be necessary to provide a dwelling on the site. The intent is to prevent vandalism and, more importantly, to correct greenhouse mechanical failures promptly. However, providing a dwelling on site is expensive, and a more desirable arrangement is for the employee to live off the nursery site but nearby.

4.18 Site Evaluation

Site selection can involve interacting factors of different degrees of importance. Sometimes one or a few factors are so important that the site selection is easy. At other times, the mix and relative weights of selection factors are so complex that selection is very difficult. In complex situations site alternatives can be arrayed opposite positive site attributes (McDonald 1976). The site attributes or elements can be weighted according to their relative importance in relation to economics, energy, personnel, finances, distance to market, politics, and other factors.

Table 4-3 in an example of such an analysis. The elements listed are not all inclusive, and each analysis will probably have different elements with different weights. Each element is rated for each alternative location on a scale from 1 to 10. The alternative rating for each element is then multiplied by the "weight" of the element. This element weight indicates relative importance of the elements, on a scale of 1 to 10. The products of element weight and alternative rating (importance) are totaled. If the alternative ranks and element weights truly reflect the advantages and importance, the alternative with the highest numerical value should be the most advantageous. This matrix is a simplified version of the type suggested in the Kepner-Tregoe decision-making procedure (Kepner and Tregoe 1965).

4.2 Economics of CTS Nursery Development

4.21 Economic Data

The first step toward entering the CTS greenhouse business is an economic feasibility study. Such studies normally examine both marketing and production. However, problems arise when this approach is taken with tree seedling production facilities. The production portion of the study can be quantified easily, but the marketing portion will often suffer from unsufficient data about market size and strength. If the only buyer is the company or agency developing the facility, the market is easily analyzed. For other situations, data on market size and the prices are hard to obtain. Without data on market size and prices, the optimum scale of facility development, product mix, and product pricing can only be guessed.

There is little published information about how containerized tree seedlings perform compared to bare-root seedlings (Owston and Stein 1974). Data are fragmentary, and results are hard to generalize. Although a number of large companies are accumulating data now for specific areas, good information for the variety of site conditions in the West may take years.[2] This makes sound analyses of market potentials for containerized seedlings difficult. The higher cost of containerized seedlings may be justified only if the cost per established tree relative to bare-root seedlings is favorable.

The technology of container seedling production, container shape and size, transport, and handling and planting in the field, is still rapidly evolving (Owston and Stein 1974), so, cost and field performance data quickly become obsolete.

The container planting system is new and glamorous compared to traditional nursery methods. Its advocates tend to be zealous about both real and unproven advantages of the system. In most cases, specific data do not exist to prove or disprove many claims about it. With a few notable exceptions,[5] much of the available data is biased and difficult to use for objective feasibility studies.

There are good reasons for the lack of market information. The product has not been fully evaluated. Its value to the buyer is difficult to assess. Pricing must be competitive with other producers,

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[5] *Personal communication with James Arnott, Forestry Officer, Canadian Forestry Service, Pac. For. Res. Centre, Victoria, B.C.*

Table 4-3.—Site selection matrix.

Elements (rate 1-10, 5 average)	Element weight	A		B		C		D		Contract		Combination of one or more	
		Rank	Prod.	Rank	Prod.	Rank	Prod.	Rank	Prod.	Rank	Prod.	Rank	Prod.
Advantage of assoc. w/ existing unit—Administration	6	8	48	3	18	10	60	2	12	8	48	5	30
Advantage of site now being available	10	10	100	7	70	8	80	0	0	7	70	5	50
Advantage of utilities on site	7	10	70	8	56	10	70	0	0	8	56	5	35
Advantages of closeness to market—Short term	6	10	60	4	24	4	24	5	30	5	30	5	30
Advantages of knowing fuel available now	10	7	70	6	60	7	70	7	70	8	80	5	50
Advantages of not having to build a headhouse	4	10	40	0	0	10	40	0	0	7	28	5	20
Advantages of being on economic-sized unit (economy of scale)	9	7	63	5	45	10	90	5	45	7	63	0	0
Advantages of control of quality	5	10	50	5	25	5	25	5	25	7	35	2	10
Advantages of full use of output	3	10	30	7	21	10	30	7	21	10	30	3	9
Advantages of nursery experience at site	2	7	14	0	0	10	20	0	0	7	14	5	10
Quality of greenhouse site— (heat reg.) (labor) (material & supp.)	6	3	18	3	18	6	36	8	48	8	48	5	30
Benefit to state forestry (and other agencies)	1	2	2	10	10	5	5	5	5	3	3	5	5
Benefit of economy of scale	1	10	10	0	0	0	0	5	5	0	0	2	2
Time to execute (time constraint)	5	10	50	5	25	10	50	3	15	5	25	2	10
PRODUCT TOTAL			643		372		600		276		530		291
Relative desirability			1		4		2		6		3		5

and there is some undefined demand for containerized tree seedlings, but it still appears to be a buyer's market.

4.22 Development Tactics—Alternatives

Limited development for evaluation.—This is a safe course, one that many have followed. The economic risk is low, because the amount invested is limited. The twin goals of (1) acquiring the technical capability to produce seedlings and (2) finding out how they perform in the field can be satisfied. Later decisions to expand or abandon the effort can be based on the added data obtained. The major drawback to this approach is that the economic benefits of a large scale operation are lost. Unit production costs will be high. This is true of most pilot projects and should be expected.

Lack of other sources and immediate need.—One of the advantages of container seedling facilities is that they can be developed rapidly just about anywhere. If an accelerated planting program is initiated, an agency or company can produce container seedlings rapidly without the time lag and huge initial expenditures required for bare-root nursery development. This is one reason companies in the Pacific Northwest recently developed container facilities.

Flexibility and reliability.—The intent here is to develop a limited container seedling production facility in conjunction with a bare-root nursery. Such a complementary arrangement has a number of advantages.

1. Rapid production of seedlings in the greenhouse can fill gaps in the overall program created by crop or seed failures in bare-root production (Stein and Owston 1977).
2. A greenhouse provides highly controlled propagation and culture where seed values are high or assured plant production is crucial.
3. Nursery labor force and other facilities can be used by both bare-root and container programs with resulting economies.

4.23 Feasibility Study

The procedure for conducting a feasibility study outlined below is based on work by Love (1975). Several basic questions need to be answered at the outset:

1. What species of trees in what size containers will be produced?
2. Where will these trees be planted, and what price would purchasers be willing to pay?
3. How much will it cost to produce the seedlings?
4. How many trees are needed?
5. What are the climatic and environmental constraints?
6. What are the management, land, labor, and capital requirements, and can these resources be secured?
7. What risk factors are involved (can the product be reliably produced, will it be accepted, can the investment be recovered in a reasonable time)?

4.24 Market Evaluation

Organizations contemplating creation of an internal CTS operation can do so without assessing demand, even though such an evaluation may be wise. Those planning production for others must evaluate markets to lessen investment risks. The market may be difficult to assess, but crude estimates are better than none, because overestimation can lead to serious consequences.

Potential market.—All potential customers should be contacted and information on the type and quantity of seedlings desired should be collected. The largest potential buyers should affect location of the facility, because CTS transport costs can be high (Colby and Lewis 1973). Separate clusters of demand may argue for smaller separate facilities.

Time of marketing.—Containerized seedlings may permit extension of the planting season (Stein and Owston 1977, and Mann 1977). Containerized trees, properly hardened, can be shipped any time of year. Depending on the nature of the planting sites and the volume to be planted, this can affect the market greatly.

Grade and quality of seedlings.—Only very high quality seedlings should be produced, because the cost of each tree is substantial. In addition, high transport costs preclude shipment of poor quality trees.

Species and container sizes.—Requiring a variety of species and containers increases the complexity of operation, which affects cost.

Transportation.—Containerized tree seedlings will be transported to a number of dispersed points in the forest. Since they are bulky and transport costs are high, the nursery should be centrally located to minimize haul distances. Estimated size of orders can also influence nursery location and mode of transport. Transport cost estimates may indicate more than one nursery, closer to the planting sites, to be the best solution.

Competition.—Commercial greenhouse operators are in competition with other greenhouses and bare-root nurseries. This may or may not be true of public or company operations, but, if the proposed operation will be in competition with other nurseries, the effect of this competition must be carefully gauged.

Price.—Some effort should be made to evaluate the price the market will bear and the price trends. These estimates should then be compared to estimated production costs and size of the proposed installation.

4.25 Production Cost Estimation

Product cost estimates are vital. For CTS production, the information regarding production costs is fragmentary; costs are different for each case. Location, climate, size of operation, type and number of crops, and the type of fuel and facilities used all have major impacts on cost of production. In the greenhouse vegetable industry, overhead or "fixed" costs account for approximately one-third of greenhouse production costs (Love 1975). Overhead costs have been increasing rapidly as building material, equipment, and interest rates have increased. But overhead, as a percentage of total cost, has been declining. Direct or variable costs have been increasing faster than overhead costs (Love 1975).

Overhead costs.—Overhead costs in government operations can be expected to be the same as for private industry. Even though there is no charge for capital, overhead assessments, and wage level constraints make up the difference. Indirect costs consist primarily of administrative costs and depreciation of facilities. The capital investment for the greenhouse, associated structures, and equipment may be high. As a result, depreciation per thousand plantable trees can be high (Colby and Lewis 1973).

Direct costs.—Labor, fuel, container, and delivery costs (or marketing costs) are the major direct or variable costs. All have risen sharply in recent years, especially fuel costs. Other direct costs such as water, fertilizer, pesticides, etc., are relatively minor.

1. Labor.—For tomatoes labor requirements for greenhouse production are more than twice that for normal field production (Love 1975). CTS culture is certainly not as labor intensive as greenhouse tomato culture, but may be more intensive than bare-root tree culture. The authors find that labor usually accounts for about 25% of the price of containerized tree seedlings.

   Some claim the bare-root nursery system is more labor intensive than the CTS system (Colby and Lewis 1973). This disagreement will not be finally settled until better data are published, but some digression here to clarify the argument seems worthwhile. CTS prices vary from less than bare-root prices to up to three or four times more, depending on a number of variables. If CTS stock costs of $120 per thousand (M) are assumed, then estimated labor cost would be $30. If bare-root seedlings are priced at $60 per M (for 2-year-old trees), about one-third of this price is usually fixed costs ($20). The remainder ($40) is made up largely of labor for culturing and lifting and packing, perhaps as much as $30 per M or more. Then, in this example, the labor cost for bare-root seedlings is 50% of the price. From this gross comparison, which is the authors' estimate for the western U.S., it can be seen that bare-root nursery production is more labor intensive than container operations, because labor costs make up a higher proportion of the product cost. Containerized tree seedlings probably require just as much or more labor per thousand trees as is required for bare-root stock. Although the percentage of the CTS price attributable to labor is lower than for bare-root stock, the total price usually is higher. The above is often not readily apparent, because most CTS operations are small compared to bare root nurseries. There are exceptions to this generalization, however. Arnott, for instance, has indicated that western hemlock seedlings, produced in the Pacific Northwest, are considerably less expensive when produced in containers.[5]
2. Fuel costs.—Fuel costs vary considerably with type of fuel used, climate, and facility. Fuel and other utilities account for about 25% of the cost of rearing CTS in the interior west, but may be as little as 5% in the Pacific Northwest or Southeast.[2] The increasing prices and questionable availability of some traditional greenhouse fuels makes selection of heating system type and fuel important in CTS nursery economic feasibility studies (section 4.14).
3. Seedling containers.—Containers and growing medium comprise the third major category of direct costs associated with CTS production. Containers come in a myriad of sizes and forms. The types available are discussed in section 9.2. Costs of these containers vary considerably, depending primarily on their size and construction, and whether they are recycled. Most containers must be filled with some kind of growing medium. Cost of the mix depends on its ingredients and the current market price of these materials. As a rule of

thumb, the cost of container and potting mix will be roughly 25% of the price of the tree.

4. Delivery (or marketing) costs.—Delivery costs include packaging materials and transportation. Packaging methods are not standardized. Transportation costs vary with the volume and weight of the product and distance from the production facility to the delivery point. The importance of the facility placement in relation to the delivery sites has already been discussed in section 4.17. Transport costs will usually be less than 10% of the product price for containerized tree seedlings.

4.26 Feasibility Assessment

When development tactics, market evaluation, product nature and quantity, and tentative location have been resolved, the feasibility of the project should readily be apparent. The work is in the collection of the data to compare, not the comparison. If cost of producing and delivering the CTS product does not provide a reasonable price, given the other factors in the situation, the enterprise is not economically feasible. For government or a private timber company the answer may indicate if it is wise to develop a facility or to procure trees from other sources. If such sources do not exist, a feasibility study may not be necessary, but is still recommended. Such a study forces consideration of as many aspects of the situation as possible and starts the development from a firm foundation of knowledge.

4.3 Development of Greenhouse Facilities

4.31 General Discussion

One of the most confusing aspects of developing a CTS facility is selection of a design. Alternative designs and equipment are well summarized by Ekblad (1973) and, in briefer form, by Newland (1974). Both explore the relative advantages of different greenhouse component options. The list of references compiled by Ekblad (1973) is a good place to look for further sources of information. Husby (1973) gives an excellent procedure for choosing the design of a greenhouse system for growing forest tree seedlings.

4.32 The Systems Approach

To assure that all considerations and requirements are drawn into the selection, a relatively simple systems analysis approach is warranted. It should be employed when there are too many factors and interrelationships to integrate without a systematic procedure. Bias and misconception can be minimized at the same time. Ekblad (1974) is probably the best reference available on the subject. In it he outlines a system design process:

"There is a temptation to look for a standard greenhouse system that is the optimum for growing containerized seedlings. Unfortunately, no single best system exists. Each species of plant has its own environmental requirement, each location has its own external environment and each manager has his own goals and cost constraints. Therefore, it would be surprising if a loblolly greenhouse in Georgia was exactly like a spruce greenhouse in Washington. What the manager needs is a total system that matches his requirements as closely as possible.

"Figure 4-3 illustrates the relationship of the greenhouse system to various requirements. Performance includes maximum and minimum inside temperatures, quantity of nutrient, quantity and quality of light, relative humidity, airflow and composition and others. Reliability includes avoidance of catastrophic failures, warning systems, and redundancy in controls. Under packaging and operability we define requirements for mixing soils, filling containers, seeding, thinning, transplanting, watering, fertilizing and preparing seedlings for transport to the planting site. Maintainability can be a tradeoff with reliability, the more reliable the systems the less maintenance required. All of these requirements are subject to cost limitations. Initial cost is important but annual fixed costs for depreciation, rent, insurance and taxes must be considered. Estimates of

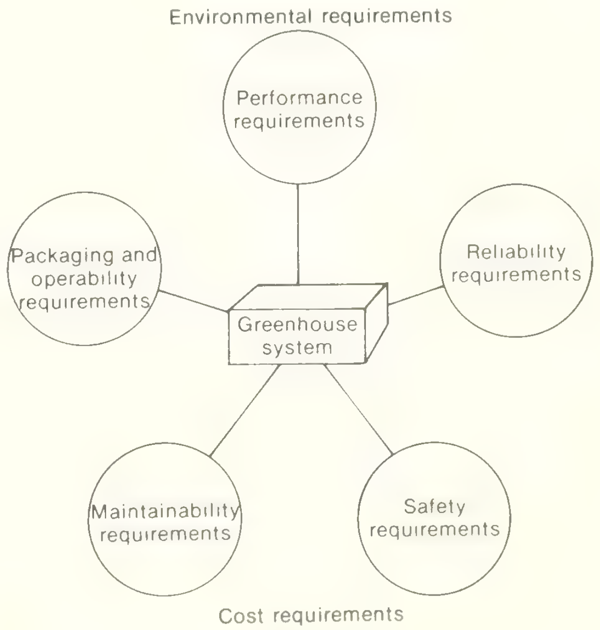


Figure 4-3.—A framework of system design (Ekblad 1974).

operating costs for fuel, electricity, fertilizer, growing media, containers and labor should be made. The manager may want to consider other less tangible costs such as cost inflexibility, possible changing land values, or energy shortages. Once a location is selected many of the environmental factors become fixed; maximum summer temperatures, minimum winter temperatures, snow loads, windspeeds, degree days, solar angle, daylight hours, solar energy, etc. If there is an option of locations this should be considered as a method of changing environmental requirements. In figure 4-4 we have a model of the systems engineering process. The process begins on the left with information. In this case it may be from a manager who wants yearly production of a number of seedlings, of a certain size and species and in a certain biological condition at a specified time within cost limits. The next step is to establish the requirements that will meet these goals. After detailed requirements are established we can look for solutions. This may be existing commercial equipment and components or it may require new designs. Concurrently, we begin technical analysis and testing, if required, to determine whether the proposed designs meet the criteria which has been established.

"I have been told that there is only one independent consulting engineer in the United States who specialized in greenhouse design. Unfortunately, there is no single book that covers all phases of analysis and designs in detail. However, there are many technical publications on greenhouse design, particularly from the American Society of Agricultural Engineers. Manufacturers and their representatives willingly supply information. Assistance is also available from engineers in state and federal government.

"The next step is evaluation and decisionmaking. The decision may be to propose new solutions and modify certain requirements.

"In summary, the system design process should an orderly, step by step process. In the case of greenhouse system it is especially important that t team include an engineer and a biological expert a that each be willing to continuously evaluate a change their solutions and requirements to meet t original goals."

4.33 Biological Considerations

The most important weight should be given those requirements that provide environment control for growing the species of tree seedlin wanted. In some instances, only a rudimenta greenhouse may be required, in others, a full controlled one is necessary. In each case, the biol gical requirements of the seedlings must be satisfie at the location specified. Several companies on th West Coast have developed semicontrolled or unco trolled facilities for containerized seedling rearin They are taking advantage of the mild, Pacif maritime climate, an option not available in mo western states. They trade climatic risk and slow seedling growth, for lower initial capital investmen Where this has been done with a sound evaluatio and understanding of risks involved, it has bee successful.

4.34 Size

The size of the projected greenhouse developme is determined by the size and number of trees to reared and how long each crop will be in the hous Often, more than one crop is grown per year in greenhouse. This can occur under several circur stances.

1. The trees reach the required size in less than months, making it possible to rear two or mo crops a year.
2. One crop of large trees, taking perhaps months to grow, is followed by another cr that can be grown in 4 months.

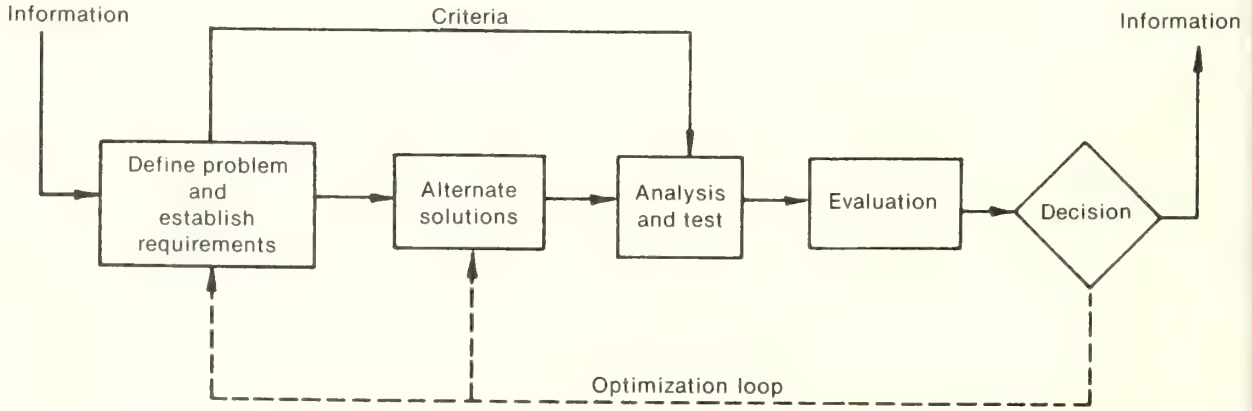


Figure 4-4.—Model of the system-design process (Ekblad 1974).

3. For one of two crops grown in the greenhouse, it serves only as a starting facility. The started crop is transferred to another growing site, such as a shadehouse, for continued growth. The second crop is then started and grown in the greenhouse.
4. The greenhouse serves only as a starting facility. Crops are started and then transferred elsewhere for growth to full size (finishing).

In other cases, only one crop may be grown per year in some greenhouses. This is true if the species grown is slow-growing, the container size is large, or it is biologically or economically advantageous. It can occur where the crop is ready in less than a year, but trees are left in the greenhouse for protection from winter temperatures, excessive rainfall, or for dormant season storage. The time the seedlings are in the greenhouse, and the resultant area of greenhouse space required, depends a great deal on the climate of the site selected. Options for utilization of the greenhouse space are more numerous in mild climates. In very cold climates, fuel costs may be so high only summer operation of the greenhouse is economical. The space required depends on:

1. The number of seedlings to be grown per year.
2. The percentage of seedling survival in the greenhouse.
3. The number of crops to be grown per year.
4. The numbers of months of operation per year.
5. The net usable bench space planned per house.
6. The type of container used.

The ability to grow a CTS crop of a certain species and size in a given time is discussed in Section 15. A procedure to convert this into a seasonal cycle and then calculate the actual greenhouse space needed is covered in section 5.3. Size of other buildings, etc. is discussed in section 7. In the initial planning phases of a project, detailed information is not needed to estimate size of a development and its cost. Final design efforts will take care of details once the decision is made to go ahead.

4.35 Summary

The demand for CTS planting stock, either real or projected, must be the starting point. Product demand, integrated with the biological requirements of the species selected and the climate at the proposed site, provide parameters for greenhouse design and scale. Several design alternatives will probably be viable. The one finally selected will depend on factors such as available capital, perspective, etc., but the overriding consideration is that the design selected must be capable of controlling the growing environment to successfully meet the biological requirements of the species.

SECTION 5.—GREENHOUSE FACILITIES

5.1 Greenhouse Framework and Covering

5.11 Structures

5.12 Covering

5.2 Layout and Orientation

5.21 General Discussion

5.22 Ridgeline Orientation

5.23 Shadows

5.3 Number and Sizes of Greenhouses Needed

5.31 Starting Information and Assumptions

5.32 Space Calculation Example

5.33 Calculation of Dimensions and Interior Arrangement

SECTION 5.—GREENHOUSE FACILITIES

The first step toward selecting the components for a greenhouse facility is to consider how much modification of the natural environment is required to produce the required size of seedling in the time allowed. Biological requirements in general and specific requirements for many species are presented in later sections, and the reader should consider these before making a final selection of hardware. Later sections also tell why various greenhouse components are needed and how necessary they are.

This section briefly explains common greenhouse designs and lists the advantages and disadvantages of the materials currently available for their construction, but gives little operational and biological detail. Information on why components are needed and how necessary they are is covered in later sections.

How to orient the greenhouse and locate it properly with respect to obstacles that cast shadows is explained in detail. The procedure for determining number and size of greenhouses and bench layout within each is presented using specific examples.

A brief cogent primer which provides a rational basis for design, selection of equipment, and operation of practical and efficient greenhouse climate control systems has been published by Augsberger et al. (1975).

5.1 Greenhouse Framework and Covering

A wide variety of greenhouse structures an covering materials are available. The traditiona glass greenhouse is only one of several options available. Several plastics are suitable for greenhouse coverings, and structures have been designed to be compatible with the physical properties of plastic.

5.11 Structures

In a commercial greenhouse, the structure is intended to provide support for the covering materia and suspend certain auxiliary equipment. Th structure should cause a minimum of shading durin daylight hours.

Supporting structures for commercial greenhouse can be grouped into four categories: rigid frame truss support, column support, and air supported Four common rigid frame structures are shown i figure 5-1. They can be covered with either flexible o rigid plastic; the frames are usually spaced on 4-foo centers. These frames have a lateral outward forc induced at the ground level. Therefore they must b restrained by foundations, footings, or pipes.

Originally, a single layer of film plastic was used a a covering, but double layer plastic has been s successful that it is now used almost exclusively. Th double layer film is separated by air pressure from small centrifugal blower. Commercial models have continuous clips that hold the plastic in place. This provides a very tight, well insulated house and overcomes the tendency to tear and flap in the wind.

Usually, the end walls are covered with a rigid plastic, regardless of whether the top is film or rigid. This facilitates framing around doors and other openings. Recovering is also simplified if rigid plastic is used over the first section that has cutouts for heaters, etc.

Examples of truss and column supported structures are shown in figure 5-2. These structures were widely used for glass houses. Some have been adapted to plastic covering. They can be used to cover wide spans, but they tend to create shading or restrict movement because of interior supports.

Almost any of the freestanding structures shown in figures 5-1 and 5-2 can be adapted to connected units as shown in figure 5-3. This arrangement reduces heat losses and uses less land. However, the units also shade each other on short winter days because of the low sun angle, allow diseases to spread more quickly, and are more susceptible to breakage from snow load.

A summary of several types of frames is given in table 5-1.

Miscellaneous construction tips.—Paint wooden structures white to increase reflectance. In snow areas have roof of at least 5/6 pitch to slip snow from a plastic house. Allow enough space between houses for accumulation of the snow that falls from the roof. Never treat greenhouse wood with pentachlorophenol or creosote, as the fumes may kill plants; use copper salts and paint. Concrete foundations may be used but are not necessary. Consider protection from rodents and birds.

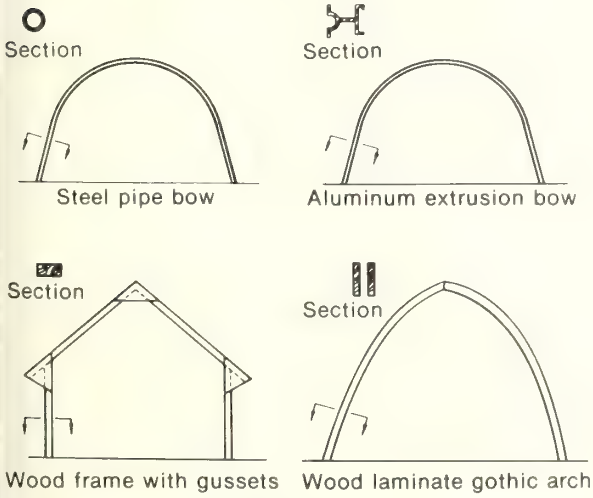


Figure 5-1.—Freestanding rigid frame structures (Ekblad 1973).

5.12 Covering

There are basically three types of covering material for greenhouses. These are glass, rigid plastic, and plastic film. There are several factors to consider in selecting a type of covering material:

(1) Solar energy transmitting properties (table 5-2)
(2) Heat transfer properties (table 5-2)
(3) Weatherability
(4) Susceptibility to vandalism
(5) Support structure required
(6) Ease of construction
(7) Condensation of water
(8) Cost (Table 5-3)

Duncan (1972) summarized the general characteristics and performance data of the more widely used materials.

Polyethylene (regular and UV stabilized).—

1. Lowest cost covering, but must be replaced periodically.
2. Widely available, although some manufacturers report recently they have stopped production of this product for greenhouse use. Be cautious about buying any product of unknown quality for greenhouse use.
3. Relatively short life in the sun: regular—9 to 11 months, UV stabilized—14 to 30 months.
4. Splits easily at the folds. Use unfolded or lay-flat rolls for maximum life.
5. Transmits approximately 85-88% of the sun's light.
6. Transmits all wavelengths of action spectra required for plant growth.
7. Transmits the wavelengths of thermal radiation which allows the house to cool more rapidly at night.
8. The strength of the new 4- and 6-mil (100- or 150-μm) film is one to two times that of the 1/8-inch (3-mm) standard glass.
9. Permits double layer covering, which results in 35-40% reduction of heat loss, reduced condensation, and only 8-10% reduction in light due to the second (clean) layer.
10. Provides a tighter house with less air leakage, which causes somewhat higher inside humidity.
11. Most useful for low cost temporary or seasonal coverings.
12. Polyethylene film reinforced with synthetic fibers is also available at a cost four to five times that of regular film, but generally this material is not used for greenhouses.
13. Double layer covering on top side of structure with centrifugal fan developing pressure between the two layers is a way to reduce labor and installation costs. Life equal or better than that of conventional installation methods.

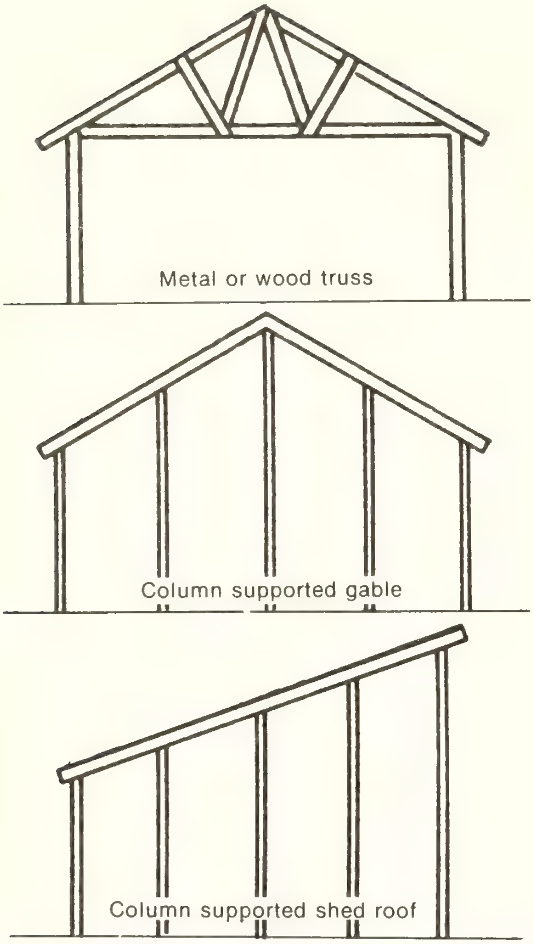
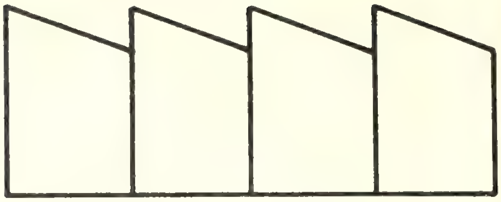
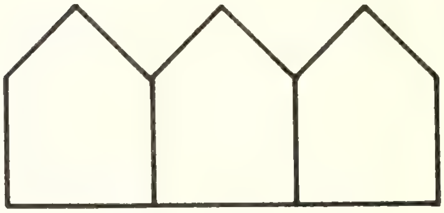


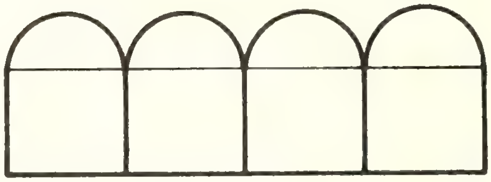
Figure 5-2.—Freestanding column supported or truss frames (Ekblad 1973).



Sawtooth



Ridge and furrow



Connecting pipe bows

Notes:
Pipe usually supported at connecting walls
Each section may be open or closed to adjacent sections

Figure 5-3.—Connected versions of freestanding frame (Ekblad 1973).

Table 5-1. Greenhouse frame.

	Covering				
Frame	**Glass**	**Film plastic**	**Rigid plastic**	**Commercially available**	**Comments**
Steel pipe bow		X	X	Yes	widely used for film plastics, minimizes shading, inexpensive.
Aluminum extrusion bow		X	X	Yes	deluxe version of steel pipe bow.
Wood frame with gussets		X	X	No	easily fabricated, considerable shading, plans available.
Wood laminate gothic arch		X	X	Yes	very lightweight, uses very little wood, plans available.
Metal or wood truss	X	X	X	Yes	widely used for glass houses, considerable shading when wood is used, suitable for wide spans.
Column supported gable	X		X	Yes	widely used for glass houses, restricts movement, suitable for very wide spans.
Column supported shed roof	X		X	No	simple construction, frequently used in connected houses.

Table 5-2.—Sunlight transmittance and radiant heat loss protection of common covering materials (Hanson 1963, Duncan and Walker 1970, Cathey 1961).

Material	Percent transmittance (0.4-0.7 μm)	Percent radiant heat loss protection
Window glass (94 mil)	89	93
Polyethylene film (no condensation)	73	26
Fiberglass (15% acrylic modified tedlar coated)	90	99

Vinyls.—

1. UV stabilized forms are more resistant to sunlight than polyethylene and last 2 to 5 years.
2. Cost is 3-10 times that of polyethylene, depending on thickness.
3. Made in narrow widths (5 to 7 feet). Must be heat-seamed together by manufacturer for wider widths.
4. Soft and pliable material.
5. The material tends to be electrostatic, which causes it to collect dust and dirt. This necessitates regular cleaning.

Polyvinylfluoride.—

1. The Tedlar® film has proven to have excellent weatherability, but is too costly to compete with other films as a covering. It is being used as a surface coating which is molecularly bonded to fiberglass panels to improve their weatherability.

Polyvinylchloride (PVC).—

1. Transparent to solar radiation, but the unprotected polymer darkens during weathering by the influence of UV rays. Most of the materials have not been suitable for more than 2 to 4 years as a greenhouse covering and, therefore, are no longer advised for greenhouse use.

Plexiglass®.—

1. An acrylic plastic that has been available for many years but has not been widely used as a greenhouse covering because of high cost, except for special climatic or conservatory type facilities.
2. It is much more resistant to impact than glass.
3. Transmits approximately 90-92% of available sunlight and is available in UV-transmitting and UV-absorbing types.
4. Has long life and weathering resistance compared to glass.
5. Softer than glass; it is easily scratched and is sensitive to some solvents.
6. Costs appreciably more than glass and other possible covering materials.
7. Flexible enough to be used as curved panels in glasshouses.
8. Strong enough to resist snow and ice loads near gutters of connected houses.
9. Expands and contracts greatly with temperature changes and should not be directly nailed or screwed down but held under a cover strip with soft mastic sealer to allow movement.

Fiberglass reinforced rigid plastics (FRP).—

1. Many brands of the polyester resin reinforced with fiberglass are available in flat and corrugated forms. Corrugated form adds strength.
2. Made in weights from 4 to 8 ounces per square foot (1.2-2.4 kg/m^2), widths up to 51½ inches (131 cm) (48-inch (122-cm) coverage), and lengths precut up to 30 feet (9 m) or more on special order. Use minimum numbers of joints and laps to reduce chances of dust and dirt accumulation between panels and also air or water leakage. Use proper clear sealer on laps for tightness.

Table 5-3.—Comparison of greenhouse covering costs (1972 Dollars) (Duncan and Walker 1972).

Material	Initial cost ¢/ft^2	Installation labor cost ¢/ft^2	Years expected life	Maintenance cost, aver. per year	Cost per year per ft^2
Poly (4, 6 mil)	1-1½¢	1½-2¢	1	—	2½-3½¢
Poly UV (4, 6 mil)	2-2½¢	1½-2¢	2	—	2-2½¢
Fiberglass, 15% acrylic modified					
(4 oz.)	20-25¢	1½-2¢	8-10	1½¢	3-3½¢
(5, 6 oz.)	30-35¢	1½-2¢	12-15	1½¢	2¼-2½¢
Tedlar Coated, (5, 6 oz.)	40-55¢	1½-2¢	15-20	½¢	2½-3¢
Glass	50¢	2-3¢	30 +	1-1½¢	2-3¢

3. Cost ranges from 20 to 30 cents per square foot ($2.15-3.20/m^2) for 4- to 5-ounce (1.2-1.5 kg/m^2) panels, 30 to 35 cents ($3.20-3.75/m^2) for 6-ounce (2.4-kg/m^2) panels, and 45 to 55 cents for Tedlar coated panels. Culls (Grade B) and assorted lengths are sometimes as low as 15 cents per square foot, but be cautious of the quality of these products.
4. Two to four times more resistant to impact and lateral loading than glass. Crazing (not shattering) usually results from impact, but this crazing has no harmful effect unless the panel surface is cracked or broken.
5. The polyester of the panels burns freely and rapidly; entire houses have burned in approximately 10 minutes. Flame retardants and good weatherability have not been successfully combined. Insurance on fiberglass is not easily obtained.
6. Clear or frosted panels of greenhouse-quality material transmit approximately 78-90% of available light when new. Non-greenhouse formulations, especially colored panels, should be avoided.
7. Panels with 15% acrylic additive have proven more durable than straight polyester formulations.
8. Acrylic modified polyester panels need cleaning at least annually, and generally resurfacing with an acrylic liquid sealer every 4 to 5 years to restore weathered surfaces to near-new transmission and surface condition (except Tedlar coated). The durability of the sealer coat is questionable and is under study.
9. Some manufacturers' guarantees are rather nebulous. Until accurate evaluation procedures and quality standards are established, judge a product more on its performance and company reputation than by the guarantee.
10. Proper attachment to the structure and sealing and fastening of lapped joints are essential for resistance to wind forces. (Use fasteners every 8 to 12 inches (20-30 cm) on ends and sides, or follow manufacturer's specifications.)

Regular Glass.—

1. Single strength and small panels are not used much on newer designs and constructions. Replacement of panes in existing houses should be with double-strength glass for more resistance to breakage.

Tempered Glass.—

1. Two or three times stronger than regular glass.
2. Frosted or "hammered" types available for better light.
3. Larger pane sizes permit fewer structura members; hence, less shadows.
4. Requires special structural members an glazing methods to give water and airtigh construction.

Figures 5-4 and 5-5 give spectral transmissio curves for several covering materials. Some of th materials have a very high transmittance in the infrared. This causes greenhouses covered with hig transmitting materials (e.g., polyethylene) to coo very rapidly at night. Table 5-4 gives the therma transmittance for several typical materials.

Table 5-4.—The mean thermal radiation transmittance o selected materials (Walker and Slack 1970).

Material	Transmittance percent
Glass 3/32 inch thick	4.4
Polyethylene 4.70 mil	70.8
Polyester 5 mil (mylar)	16.2
Polyvinyl chloride	12.0
Resin bonded fiberglass	1.0

In summary, the best greenhouse structure an covering is one which fits the goals and constraints o the developer. The cost or structural features shoul not be the only consideration in selection. The greenhouse is an engineered system with interactiv components. For example, a structure with high hea losses will require greater heating capability an more fuel. Consultation with agricultural engineers the local greenhouse industry, and the local greenhouse supply industry can guide the develope

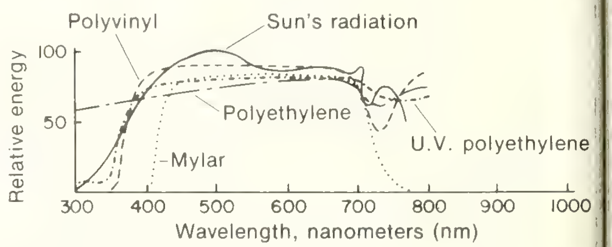


Figure 5-4.—Spectral transmittance of selected film greenhouse coverings (Walker and Slack 1970).

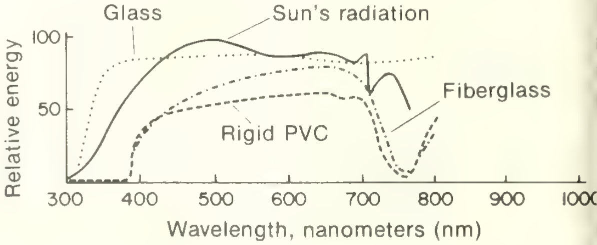


Figure 5-5.—Spectral transmittance of selected rigi greenhouse covering materials (Walker and Slack 1970).

around many pitfalls. Contact the state agricultural extension service, or state university engineering or horticulture department for advice.

5.2 Layout and Orientation

5.21 General Discussion

The general layout of a CTS nursery should permit maximum production efficiency. This is the second axiom of CTS operation development, especially in large operations. (The first axiom is provision for a biologically sound growing environment). Hoenke (1974) lists basic steps to accomplish this goal.

Select container handling system.—If this is speculative because of lack of experience, the system should be as flexible as possible so it can accept a variety of types and sizes of containers and pallets, etc. The planner should decide if the system is to accommodate a forklift or other rolling stock for moving trees.

Determine greenhouse size.—This depends on species to be grown, containers to be used, and dates of shipment to be targeted, as well as economics and availability. A greater number of small houses can provide the grower with more product and delivery flexibility than a few large ones. It also means more equipment, more duplication and redundancy, more exterior wall area to heat, etc., which increases fixed and variable costs. Therefore, a good balance between the efficiencies of larger houses and the flexibilities of smaller houses is needed.

Plan access to the greenhouse.—Quick and easy access should be provided to all greenhouses. The spacing between houses and/or width of roads should permit access to the greenhouses by the largest equipment that will be used, allow room for snow removal, and allow adequate room for free exhaust and intake of air. Road surfaces should be smooth and firm enough for all-weather use to aid container handling and provide a sanitary surface around the greenhouses. The work center or headhouse needs to be readily accessible to the greenhouses and should be designed to provide all the necessary functions of shipping, receiving, potting, and seeding (section 7.1).

Integrate flow of materials.—The whole design should integrate all systems so that the flow of materials is constant and smooth for maximum efficiency. Several floor plans should be made and analyzed with flow diagrams made for each phase of work (fig. 5-6).

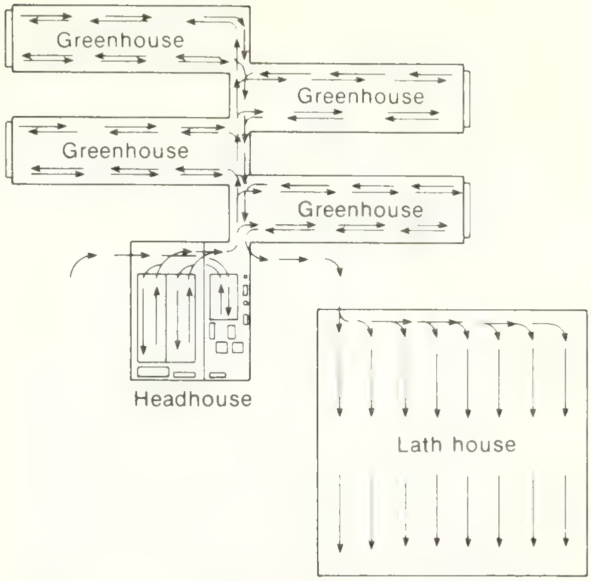


Figure 5-6.—Pallet movement diagram (Husby 1973).

Planning for growth from a pilot or trial project to a large production nursery is often a difficult development problem. Under these circumstances, the planner must foresee future expansion. Short-sighted development of trial projects with no thought of future expansion can make later expansion expensive and difficult.

5.22 Ridgeline Orientation

Maximum light transmission is needed when days are short and the sun remains low in the sky. Sun angle calculations, therefore, should use figures for the growing period when the sun is lowest in the sky. The orientation of the long axis (ridgeline) should be perpendicular to the direction from which most solar radiation comes in the winter. Bozeman, Mont. will be used as an example. During December, the solar energy arriving at the greenhouse is only sufficient to be effective between about 9 a.m. and 3 p.m. During this time, the sun altitude varies from 10.7° at 9 a.m. to 22.3° at noon, as measured from the horizontal (fig. 5-7). The bearing angle varies between 41.5° east of south to 41.5° west of south (Husby 1973). This indicates that an east-west ridgeline orientation is necessary.

At Bozeman, during December, the mornings tend to be more cloudy than the afternoons (Husby 1973). To take advantage of this phenomena, a slight cant of the ridgeline to the northwest would be required.

This calculation could be modified for the same location if, for instance, a mountain blocked the sunrise until 60° south of east and at 20° elevation at 10:30 a.m. Under these circumstances, the ridgeline would be canted more to the northwest-southeast line to capture the maximum amount of energy available from the daylight in December.

At lower latitudes, where the sun is higher in the sky in the winter or crops are not actively growing in midwinter, this orientation of the ridgeline will not be so important. Often, greenhouses are constructed with the ridgeline on a north-south line when the south endwall is transparent (except possibly for exhaust fans) and cooling pads are placed at the north wall. This orientation is usually satisfactory for tree growth, especially when coverings, such as plastic film or fiberglass, are used that diffuse the light and eliminate most shadows.

5.23 Shadows

Shadows from adjacent greenhouses.—Where several greenhouses are to be placed in a parallel arrangement, avoid having one greenhouse shading the next one. Such shading can be eliminated by simply providing a large allowance of space between greenhouses. A more realistic approach, because of high real estate costs, is to minimize the space required between greenhouses. This can be done by making a couple of assumptions and a few calculations. The information needed is:

1. The height of the greenhouse structures from the ground to the top of the ridge of the roof.
2. The angle of the sun from the ground at the time of day at the time of year for which the calculations are made.

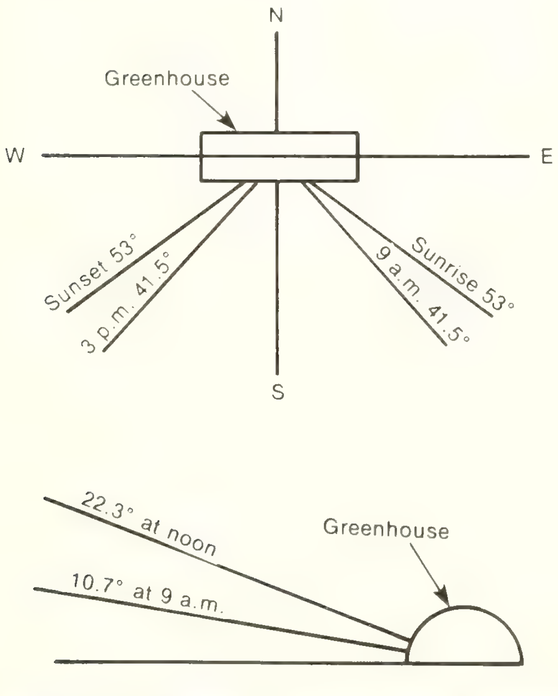
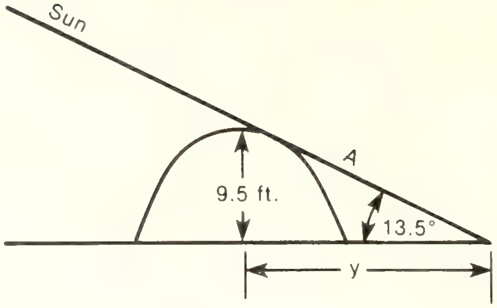


Figure 5-7.—Sun altitude and bearing angle at Bozeman, Mont., in December (Husby 1973).



$$y = \frac{9.5}{\text{Tan } 13.5^\circ}$$

$$y = \frac{9.5}{0.24}$$

$$y = 39.6 \text{ ft.}$$

Figure 5-8.—Calculation of greenhouse shadow over the ridgeline (line A) (Husby 1973).

3. The angle of the orientation of the long (lengthwise) axis of the greenhouse with respect to true north.

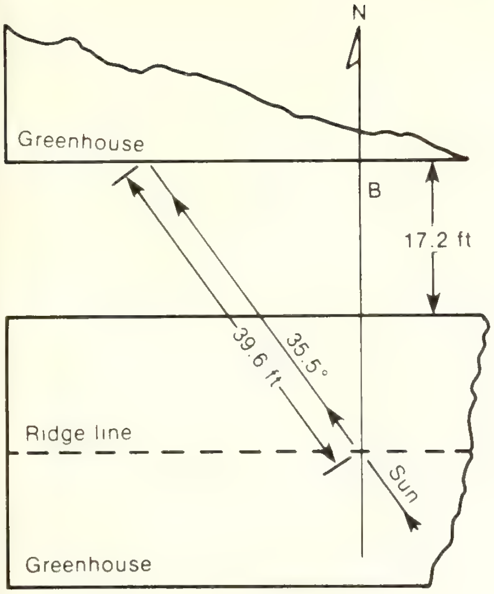
Use the method shown in figure 5-8 to calculate the length of shadow along the line of sun angle over the ridgeline of the greenhouse (Husby 1973). Next, find the length of the shadow perpendicular to the ridgeline in December (fig.5-9).

Note that in this example the ridgeline is east and west, but it may not be in many cases. Also, no compensation is made for ground slope in any direction.

Headhouse and corridor shadows.—In the design and layout of the greenhouse complex, attention should be given to minimizing the shadows cast onto the greenhouses by supporting buildings or structures. This can be done by placing opaque structures such as cooling pads or headhouses, on the north side of the greenhouses. Cooling pad systems along the sides of the greenhouses (cross-flow cooling) should be kept short enough to be below crop height in the house.

Where a corridor is necessary with greenhouses branching off from either side of it, some shadows cannot be avoided. However, the effect can be minimized by constructing the corridor of transparent or translucent materials.

In summary, structure shadows can be compensated for by a thorough greenhouse planner. Th planner should also note the surrounding trees tha could cast shadows on the greenhouses. The probability that someone might construct a large building on adjacent property that would shade the greenhouses should also be considered. This is a problem of "solar right-of-way" which is important for greenhouses and solar-energized buildings.



$z = 39.6 \cos 35.5°$
$z = 39.6 \times 0.814$
$z = 32.2$ ft

Minimum space, m
$m = 32.2 - 15$
$m = 17.2$ ft

Figure 5-9.—Calculation of greenhouse shadow perpendicular to the ridgeline (Husby 1973).

5.3 Number and Sizes of Greenhouses Needed

5.31 Starting Information and Assumptions

The following must be known or assumed to complete these calculations.

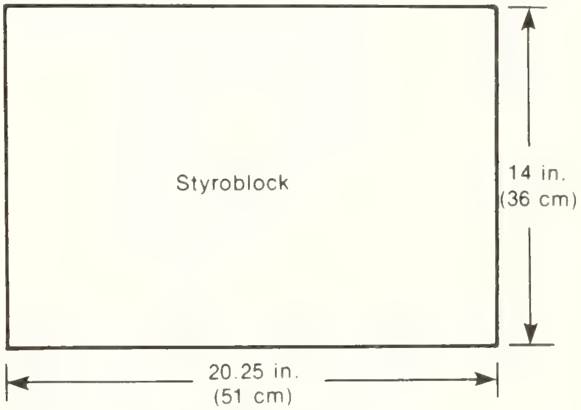
1. How many trees are to be produced per crop?
2. How many different growing environments will be required to produce the crop (i.e., how many different tree species requiring separate environments)?
3. What containers are to be used?
4. Will these containers be placed on pallets, benches, or other systems?
5. What are the minimum aisle widths? This ties into the proposed system of moving the containers.
6. What are the target dates for seedling shipment?
7. How long will it take for the species to be grown to fill the containers adequately and to reach shippable size?

If these items are known, then the greenhouse space required, the different environments necessary, and the number and size of greenhouses needed can be calculated. The greater the number of species to be grown and the greater number of container types and sizes to be employed, or shipment dates needed, the more complicated the procedure will be.

If some assumptions are made at the outset as to size and type of house, the calculations are greatly simplified. Following is an example from Ekblad (1973), where a size of greenhouse is assumed and a container type is selected. The result is a straightforward calculation. Assume that space must be provided for 1 million trees per crop. Houses are available commercially 30 feet (9.3 m) wide and 96 feet (30 m) long. Trees are to be grown in styrofoam containers. The styroblocks are to be placed on pallets, which can be rolled into and out of the greenhouse on permanent tracks. Dimensions of an available styroblock container are given in figure 5-10.

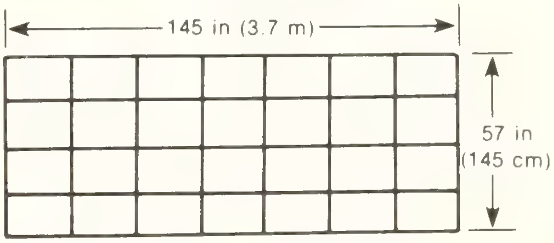
A convenient size of pallet is considered to be about 12 by 4 feet (3.7 × 1.2 m).

Consider the styroblock layout in figure 5-11. This means pallet dimensions must be 4 feet 9 inches by 12 feet 1 inch, which allows 3 feet of aisle with 1½ feet



192 holes per block
Holes - 16 x 12

Figure 5-10.—Dimensions of an available styroblock (Husby 1973).



Pallet dimensions - 4 ft 9 in x 12 ft 1 in
(1.47 x 3.74 m)

4 x 14 in = 56 in
7 x 20.25 in = 141.75"
Allow 1/4 in. space (6 mm)
between each block

Figure 5.11.—One possible layout of styroblocks on a large pallet (Husby 1973).

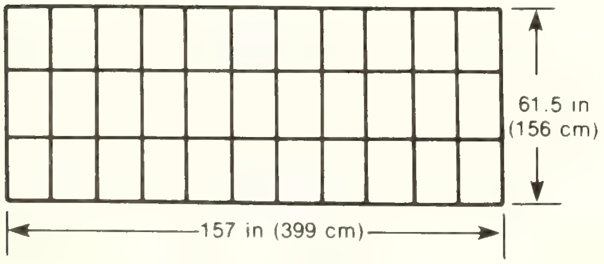
of space at each wall. Allowing 2 feet between pallet and cooling pad provides 94 feet of growing area, with 20 pallets along one side with 40 per house. Number trees = 40 × 28 × 192 = 215,000 trees per house. Trees per crop = 4 × 215,000 = 860,000 trees per crop (no blank cavities).

Consider an alternate styroblock layout (fig. 5-12). This results in a pallet 5 feet 1½ inches by 13 feet 1 inch, which allows a 2-foot (60-cm) aisle with 1 foot (30 cm) of space at each wall, and 3.5 feet (1.1 m) between pallet and cooling pad. There would be 18 pallets along one side, with 36 per house. Number of trees = 228,000 per house. Number of trees per crop = 910,000. The difference in width between these two layouts is small. Therefore, the 13 by 5 foot (40 by 1.6 m) pallet appears to be the better choice. Using the larger pallets can produce 100,000 more trees per year.

However, if very few specifications have been placed on the nature of the projected operation, the calculations become very complex. Usually, the developer will have some of the information necessary to do the calculations; values for other items must be assumed. Following is a discussion of each question in more detail.

How many trees are to be produced per crop?—If the initial goal is pilot testing the container systems or testing the market, the scale of production will probably be small. These calculations are then greatly simplified. Some level of production must be targeted at the outset.

How many different growing environments will be required to produce the desired crop(s)?—See sections 10 and 12 for information on the biology of different tree species and their compatibility in the greenhouse. Other considerations are the duration of the rearing period and the target date(s) for seedling delivery. The major tree species to be grown and when they are needed is usually known.



3 x 20.25 in = 60.75 in
11 x 14 in = 154 in
Allow 1/4 inch space (6 mm)
between each block

Figure 5-12.—An alternate styroblock layout (Husby 1973).

The duration of the rearing period for each tr species is estimated, based on the experience others, then refined by the nurseryman's own expe ience (section 15).

What containers are to be used?—A large varie of types and sizes of containers are available (secti 9.2). Each type has its advantages and disadvantage The greenhouse developer should select contain types and sizes he wants to field test or sell. Th selection should be based on the best local knowled concerning:

1. The minimum size that will produce good see ling survival for each species, and
2. The type of container that will work best giv local transport and planting methods. In a ne development, a variety of types and sizes w probably be desirable, with fewer used after t trial period. It is easier to select one or tw types and sizes to use for most of the gree house space, and limit trials of other types a sizes to small numbers. The greater the numb of container sizes and styles employed, t more complicated space calculations a Often, a single style is chosen to simplify calc lations, although several types will be e ployed.

What kind of greenhouse benches will be used?— Will the containers be placed on pallets, benches, o some other support system? Such systems a discussed in detail in section 7.4. The handli system will affect greenhouse space estimates. T problem is fitting the containers on the su port/handling units. Sometimes greenhouses a built without regard to container size or ben configuration. Benches and containers are then fit in a haphazard way following construction. This not a recommended practice. The support syst should be selected before construction.

What are the minimums for aisle widths and oth spacing?—This must be a part of the suppo handling system plans. Aisles and doors must b wide enough to accommodate a forklift or a pal system if these are to be used. Aisles are also need for inspection and thinning operations and to all air circulation. Some systems have fixed bench with a few narrow aisles and a moving platfo which can carry workers over the trees for thinni etc. Sometimes the benches slide or can be moved create a walking space, but elsewhere there is a so array of trees. The most common system is bench or tables to hold the containers with a center aisle medium width and permanent, narrow, lateral ais between benches. This last system is probably cheapest to install, but sacrifices some greenho oom to lateral aisles that otherwise could be used for roduction.

Usually, 1 or 2 feet (30-60 cm) of space between the reenhouse wall and the benches is provided. The easons for this are (1) to keep the plants away from ot or cold air flow immediately adjacent to the xterior wall, and (2) to allow free air circulation, up nd down, along the exterior wall to minimize air tagnation.

The containers are usually placed no closer to ooling fans and pads than 2 feet (60 cm) and are ısually at least 4 to 5 feet (120-150 cm) away. This voids undue chilling of the closest plants. Similarly, plants are usually kept at least 2 feet (60 cm) away rom exhaust fans and, preferably, 4 to 5 feet (120-50 cm) away. Areas immediately adjacent to xhaust fans are subject to accelerated air velocities vhich dry the trees excessively. These floor space osses can often be retrieved by using air plenum hambers to dissipate velocity or encourage total aminar air flow within the house. However, cost of uch designs must be measured against the greenhouse space lost.

What are the target dates for seedling shipment?—f medium-sized trees are wanted in about equal numbers in the fall and spring, it may be feasible to perate a single house year round with no "down" or noperative period. However, large trees may require 10 months growth with the greenhouse inoperative or 2 months (one crop per year). Another example would be delivery of large trees in the spring and smaller or faster growing ones in the fall. Under such conditions, a crop can be reared in the house from midwinter to spring, then transferred to a shadehouse for further growth and overwintering before planting. After that crop is removed to the shadehouse, another crop is started in the late spring in the greenhouse and grown until early winter. This way the greenhouse space is used to the maximum extent. Consequently, the interaction between delivery target date, species, and container will greatly affect needed greenhouse space. These production tactics need to be determined before space calculations are made.

How long will it take the desired species to reach the size wanted?—Some information is available from research and from operating nurseries for many tree species. In other instances, guesses must be made based on growth of related species. Projected growth rates for some species are given in section 10. Each greenhouse environment is slightly different no matter how closely it is controlled. Consequently, the same trees can grow at slightly different rates in different houses, even if controlled environment settings are the same.

5.32 Space Calculation Example

Consider the following hypothetical situation (table 5-5). The trees will be grown on benches 30 inches (76 cm) high, 3, 4, or 5 feet wide and in 4-foot-long modules. There will be 18-inch (45-cm) thinning aisles between benches and a center aisle in each at least 5 feet (1.5 m) wide.

It is expected it will take species A 10 months to reach adequate size, species B 7 months, and species C four months.

Bench space necessary.—Following are the calculations, by species:

1. Species A.—Spencer-Lemaire 30 cubic inch (492 cm^3) Rootrainer® containers come four cavities to a "book" and 10 books fill the company's wire rack (see section 9.2 for discussion of container types). So, 40 cavities fit in a rack that is 11¼ by 18½ inches (29 × 47 cm) outside dimensions. Allowing an extra ¼-inch (6-mm) spacing on each side of the rack produces dimensions of 11½ by 18¾ inches (29 × 48 cm) and provides 5.39 square inches (35 cm^2) per cavity or 1.497 square feet per 40 cavities, or 3.743 square feet per 100 cavities. If a 91% success rate is assumed, about 110,000 cavities will be needed, or 1,100 times 3,743 square feet = 4,118 square feet (382 m^2) of usable bench space will be required. (Note: percent success rates are selected for ease of calculation. Normally they derive from experience.)
2. Species B.—Leach Super Cells® fit in trays with 200 cells per tray. Trays are 12 inches (30 cm) wide and 24 inches (61 cm) long. Allowing ¼-inch spacing on each side of the tray provides a

Table 5-5.—Hypothetical variables for calculating space requirements based on given production goals (M = 1,000).

Number	Species	Size	Container[1]	Season to plant
100M	A	large	30 cubic inch (410 cm^3) Spencer-Lemaire	Fall (October)
200M	B	medium	Ray Leach Fir	Spring (May)
350M	C	medium	Styroblock 4	Spring (June)

[1] *Trade names are used only for specificity and brevity, and do not imply any endorsement by USDA to the exclusion of equally suitable products.*

bench density of 97 cavities per square foot (1,045)/m^2). If a 91% growing success rate is assumed, about 220,000 cavities will have to be employed to produce 200,000 trees. Therefore, 220,000 ÷ 97 = 2,268 square feet (210 m^2) of usable bench space will be needed.

3. Species C.—The Styroblock® 4 (3.94-cubic inch (65 cm^3) cavity volume, gross) measures 13-7/8 by 23¼ inches (35 × 59 cm) and has 160 cavities. Allowing ¼-inch (6-mm) spacing on each side of the block brings dimensions to 14-1/8 by 23½ inches and produces a bench density of 69.41 cavities per square foot (748/m^2) bench space. Assuming a 90% growing success rate, 350,000 cavities will have to be sown to produce 315,000 trees. So, 350,000 ÷ 69.41 = 5,042 square feet (468 m^2) of usable bench space needed.

Number of greenhouses needed.—Greenhouse type and size are often selected before bench space needs are really known. When this is done the layout is simplified. For this example, the selection of the greenhouse size has not been made, because the species and delivery time compatibility must be considered. Let us say the growing environment required for species A is not compatible with the other species (section 10) and at least 10 months are needed for growth. From the above calculations, more than 4,100 square feet (370 m^2) of greenhouse bench space are needed.

The case is more complicated for species C (5,042 square feet (468 m^2) of space needed, delivery in June, 4 months to grow in the house) and species B (2,268 square feet (210 m^2) of bench space needed, delivery in May, 7 months to grow). Since the total growing time is less than 12 months, there is a chance two crops may somehow be produced in the same greenhouse, even though both crops are to be shipped in the spring. This possibility can easily be investigated. While the months are available in the year to grow both crops (11 needed, 12 available), the common delivery date means one crop has to be grown and wait until shipment time while the other crop is grown. Feasibility of this can be tested by constructing growing "scenarios" diagrammatically using a circle to represent a yearly cycle (fig. 5-13).

Next the projected delivery dates for the crops are located. The growing periods for one crop and then the other can be plotted around this "clock face." There are two possibilities.

First, suppose we raise species C as a winter crop and species B as a summer crop. Figure 5-13 shows that species C can be grown from mid- or late December to the May delivery time. Species B can be grown from mid-May to mid-December and then moved to a shadehouse for overwintering and shipment from the shadehouse the following June.

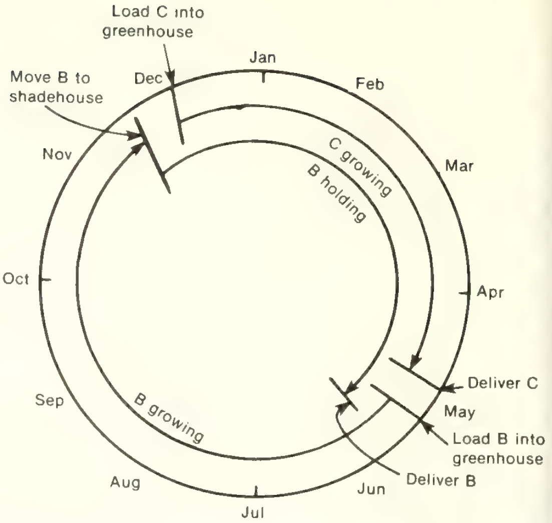


Figure 5-13.—Alternative 1. Grow species C as a wint crop and species B as a summer crop.

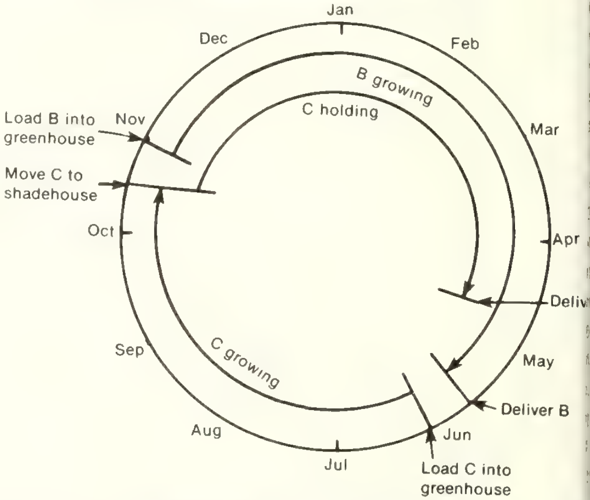


Figure 5-14.—Alternative 2. Grow species C as a summ crop and species B as a winter crop.

Holding species B overwinter in a shadehouse a pears to be feasible, if this crop can be moved to th shadehouse after it has been hardened in the gree house.

Suppose, instead, species B is grown as the wint crop. Figure 5-14 shows that species C can be grow from early June to October, then moved to the shad house to overwinter. Species B would be loaded in the greenhouse about November 1, grown to June and then shipped. Seven months are available grow species B. Holding species C overwinter in shadehouse is feasible and would be easier to execu than alternative 1. Also, species C goes into th shadehouse in October, which is biologically easi and safer. The same greenhouse facility can be use for growing both species B and C, so, alternative appears to be the growing scheme to elect. At th point, note that the culture of species C will requi about 5,042 square feet (468 m^2) of greenhouse ben rea, and species B will require about 2,268 square eet (210 m²). This means, under alternative 2, the reenhouse will be more than half empty for seven onths. This is important, since these months are igh heating cost winter months. It is possible that rovision can be made to heat only the producing alf of the house when growing species B until usiness increases.

Before the decision is made to build one green- ouse for species A and one for species B and C rops, note the similarity of bench space require- ents for species A and C (4,118 square feet (382 m²) ersus 5,042 square feet (468 m²). If there is a way to row both species in the same greenhouse, a number f other alternatives may open up, so, some inves- gation is warranted.

Species A and C can be grown in the same house, y growing species A from October to June in the reenhouse, then putting the trees into a shadehouse r the summer and delivering them in October. This eans species A would grow in the greenhouse as ng as 9 months and in the shadehouse for 4 months. pecies C would be grown in the greenhouse from ne to October and then be in the shadehouse until e following May when it is delivered. This plan ould mean the greenhouse would be operated at apacity in the summer and that another house ould be required for species B. The second house r species B could be smaller if two crops per year ere grown, an advantage over alternative 2. How- ver, this assumes that species A can finish its evelopment in the shadehouse during the summer. is reasonable to expect this, but the resultant trees ay not be what is desired morphologically.

Assumptions about how well the trees will grow in e shadehouses are tenuous without experience, and an lead to variations in stock quality and added bor. If the production goals are definite and nowledge of how the trees would respond in a adehouse is limited, it is safer to plan on two green- ouses of adequate size. Shadehouse growing could e tested later, and perhaps open the way for ex- anded production with the existing houses.

Remember that the milder the climate, the more e greenhouse may be used as a starting facility, and e greater the amount of growth that can be ex- ected in the shadehouse. Most climates are some- here between two extremes: one where the climate so mild no greenhouse is needed for adapted plants grow all year under shadehouse conditions; the ther where a short growing season means all "ac- lerated" growth must be made in a greenhouse. his manual is oriented to average north temperate nditions. Plans for greenhouse utilization outside ese conditions should take into account the dif- rence from these average conditions.

In summary, alternative 2 is the selection with one ouse for species A and another house for species B and C. Two houses with approximately 5,000 square feet (464 m²) of bench area each are needed. Since the area needed in each house is roughly the same, two very similar houses can be built. Similar houses offer these benefits:

1. Ease of maintenance
2. Fewer spare parts to stock, and interchangeability of parts.
3. Often the unit price will be a little lower when two are bought instead of one.
4. More visual harmony in the installation.
5. Greater ease of construction.

The structural types of greenhouses were discussed in section 5.1. Only dimensions will be discussed here.

5.33 Calculation of Dimensions and Interior Arrangement

It was assumed that the benches would be 3, 4, or 5 feet wide, in 4-foot (1.2-m) long modules. The center aisle is to be at least 5 feet (1.5 m) wide, and thinning aisles at least 18 inches (46 cm) wide. It is advantageous to have the same interior arrangement in each house. The planned container dimensions (including spaces between them for air circulation) are:

Species A: 11½ by 18¾ inches (29 × 48 cm)
Species B: 12¼ by 24¼ inches (31 × 62 cm)
Species C: 14-1/8 by 23½ inches (36 × 60 cm)

Assume that the parameters for greenhouse bench and aisle spacing are set by the container handling system to be used, the benches to be used, the house type, and the preferences of the developer.

Following are sample calculations for the two greenhouses, giving the containers and spacing requirements:

Species A.—A greenhouse with more than 4,118 square feet (382 m²) of usable bench area is needed. Container dimensions are 18¾ by 11½ inches (48 × 29 cm). A 5-foot (1.5-m) bench width is chosen at the outset, first, because it is commercially available. Second, with aisles on each side, the bench center can be reached for thinning excess trees. Thirty inches (76 cm) is as far as anyone should be required to reach for thinning or weeding. If the reach is further, there is too much back strain, and the work rate cannot be maintained). Third, there is no advantage of using narrow benches (smaller units) in this instance.The question then becomes how to orient the containers on a bench 5 feet (1.5 m) wide and of length, yet to be determined, to best utilize the bench width and come up with a greenhouse width which includes bench, aisle, and wall clearance. Greenhouse width should also be of common commercial dimensions and economic size. To do this, the container width and length are multiplied to reach a total width of about 5 feet (1.5 m) to see how they fit in that dimension:

With the long dimension placed laterally:

18.75 inches × 3 = 56.25 inches
60 inches − 56.25 inches = 3.75 inches unused bench width
3.75 inches ÷ 2 = 1.875 inches (5 cm) unused width on each side of bench with containers centered.

With the short dimension placed laterally:

11.5 inches × 5 = 57.5 inches
60 inches − 57.7 = 2.5 inches unused bench width
2.5 inches ÷ 2 = 1.25 inches (3 cm) unused width on each side of bench.

There is slightly less wasted space when the short dimension is placed laterally. The best width of the green house can be analyzed the same way while allowing for aisle and wall spacing. The difference is that the limit of greenhouse width is not set, as it was for the bench width. This is overcome by calculating several greenhouse widths. The standard available widths can be found for the type of greenhouse structure desired. The number of containers making optimal bench length can then be fitted into these various widths for (1) best bench space utilization and for (2) best overall greenhouse length. The greenhouse length and width also affect heating and cooling design. The greenhouse manufacturer can advise as to the best range of dimensions.

In this calculation, we will assume the best greenhouse width is 50 feet (15 m). If the specified 5-foot (1.5-m) minimum aisle is deducted, with 18 inches (45 cm) between the benches and the wall on each side (total 36 inches or 3 feet) (90 cm) the net space available for benches is 42 feet (12.8 m). It was also specified the benches would be in 4-foot (1.2-m) modular lengths. With the aisle down the center of the greenhouse, there is 42 ÷ 2 = 21 feet (6.4 m) available for benches on each side of it. Since we are confined to 4-foot (1.2-m) modules, this becomes 4 × 5 = 20 feet (6 m) and the aisle becomes 5 + 2 = 7 feet (2.1 m) wide (or the spacing from the wall can be increased). The container orientation can then be fitted to the 20-foot or 240-inch bench length.

The short dimension (11.5 inches) will fit into 240 inches 21 times, with 1.5-inch overhang or 0.75 inch on each end.

11.5 inches × 21 inches = 241.5 inches
241.5 − 240 = 1.5
1.5 ÷ 2 = 0.75.

With three tiers (from the sample calculations the first part of this section) of containers, 21 co tainers deep, there are 63 containers on a 5- × 2 foot (1.5- × 6-m) bench. The long dimension (18. inches) (47 cm) will fit into 20 feet (6 m) 13 time with a 3.75-inch (10-cm) overhang or 1.875-inch (cm) overhand on each end of the bench:

18.75 inches × 13 = 243.75 inches
243.75 inches − 240 inches = 3.75 inches
3.75 ÷ 2 = 1.875.

With five tiers (from previous calculations) containers 13 deep, there are 65 containers per 5- 20-foot (1.5- × 6-m) bench. The choice of bench and container orientation is, therefore, (1) benc dimensions of 5 × 20 feet, and (2) containers 18. × 11.5 inches oriented on the benches with the lor dimensions parallel to the bench length in five tiers 13 containers or 65 containers per bench.

Now, 65 containers per bench becomes 130 co tainers per bench tier (on each side of the cent aisle), and 130 containers cover 194.7 square fe (18.1 m^2) of bench space per bench tier (1.50 squa feet (0.14 m^2) per container times 130). Previo calculations indicated a usable bench space need 4,118 square feet (382 m^2) to rear the desired crop this type of container, so, (4,118 ÷ 194.7) = 21. or 22 tiers of such benches are needed. This figu determines the minimum length of greenhou required for species A.

It was stated that aisles between benches would 18 inches (45 cm) wide, so, 22 tiers would require × (5 + 1.5) = 143 feet (43 m) of greenhouse leng with 5-foot benches. The first containers should be least 4 feet from the cooling pads, and the last co tainers at the end of the house should be an equiv lent distance from exhaust fans. A greenhouse abc 150 feet (45 m) long will suffice, because 7,500 squa feet (696 m^2) (150 × 50 feet) of space will be need (with 22 tiers of benches 5 × 20 feet).

Species C.—A greenhouse with more than 5,0 square feet (468 m^2) of usable bench space is quired. Container dimensions are 23½ × 14-1 inches (60 × 36 cm). A 5-foot (1.5-m) bench widtl chosen for the same reasons indicated for species Calculations testing both orientations are then ma to see how many containers can be placed on t bench width:

With the long dimension placed laterally:

23.5 inches × 2 = 47 inches
23.5 × 3 = 70.5 inches
70.5 − 47.250 = 23.25 inches (59 cm) unu bench width on each side of the bench with containers centered.

With the short dimension placed laterally:

14.125 inches × 4 = 56.5 inches
70 − 56.5 = 13.5 inches unused bench width
13.5 inches ÷ 2 = 6.75 (17 cm) unused bench on each side with containers centered.

The short dimension (14-1/8 inches) should be riented across the bench in tiers of four containers ach to best utilize the bench width.

The best width of the greenhouse can be found by uplicating the calculations for species A. Again, the enches are in 4-foot-long (1.2-m) modules 5 feet (1.5) wide. As before, it is assumed the best design idth, considering model availability, cooling actors, etc., is 50 feet (15 m). Therefore, the benches gain will be 20 feet long on each side of the aisle.

Since the short axis of the container will parallel ne 5-foot (1.5-m) dimension of the bench, the long xis (23.5 inches) must be fitted to the 20-foot ngth dimension:

23.5 inches × 10 = 235.0 inches
240 inches − 235.0 = 5.0 inches unused bench depth
5.0 inches ÷ 2 = 2.5 inches (6 cm) unused bench depth on each end of the tier.

The layout is then (1) bench dimensions of 5 × 20 et (1.5 × 6 m), and (2) containers 14-1/8 × 23-1/2 ches (36 × 60 cm) on the benches oriented with the ng dimension parallel the 20-foot axis and the short imension parallel the 5-foot axis in four tiers of 10 ontainers or 40 containers per bench.

Forty containers per bench becomes 80 containers per bench tier (on both sides of the center aisle). Eighty containers (80 × 2.305 square feet) = 184.4 square feet of bench space per tier. Previous calculations indicated a usable bench space need of 5,042 square feet (468 m^2) for species C. So, (5,042 ÷ 184.4) = 27.34 meaning 28 tiers of such benches are needed. This figure determines the greenhouse length as follows:

Aisles between benches are to be 18 inches (45 cm) wide, so, 28 tiers would require 182 feet (55 m) of bench and aisle space (28 × (5 + 1.5) = 182 feet lengthwise down the greenhouse. If 4 feet (1.2 m) of space on each end is added between the benches and the cooling pads and fans, the greenhouse could be 190 feet (58 m) long.

Species B.—Because the area needed for species B is smaller than required for species C, and it will be grown in the same house, no calculations for it are needed.

This example illustrates how such calculations can be made. Other interior arrangements are feasible, but the sequence of steps and calculations would be similar. The greenhouse dimensions arrived at (50 × 150 and 50 × 190) are rather unusual. In some ways, three or four smaller units might be more flexible and desirable. However, large units are less redundant and may be cheaper per square foot of space. Much would depend on the type of structure to be used and the availability of different sizes. The developer should be prepared to change his preconceptions based on results of these calculations.

SECTION 6.—GREENHOUSE HARDWARE AND CONTROLS

6.1 Temperature Modification

6.11 General Discussion
6.12 Cooling
6.13 Heating
6.14 Winter Ventilation
6.15 Energy Conservation for Greenhouses

6.2 Greenhouse Lighting

6.21 Lamps for Photosynthesis
6.22 Lamps for Prevention of Dormancy
6.23 Lamp Arrangement

6.3 Carbon Dioxide Control

6.4 Water and Fertilizing

6.5 Controls, Security, and Instrumentation

6.51 Temperature Controls
6.52 Types of Controllers
6.53 Lighting Controls
6.54 Humidity Controls
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6.6 Greenhouse Safety

SECTION 6.—GREENHOUSE HARDWARE AND CONTROLS

This section deals primarily with the equipment incorporated in a greenhouse structure that enables it to become functional. The section is designed only to acquaint the reader with the equipment and how it might relate to seedling culture, but no detailed examination is made.

6.1 Greenhouse Temperature Modification

6.11 General Discussion

Modification of the climate within a building to provide a uniform environment is a complex problem.

Figure 6-1 indicates the most important factors influencing a greenhouse temperature environment. Some problems unique to a greenhouse are: (1) very rapid heat buildup from solar radiation, (2) rapid cooling caused by lack of insulation, (3) high degree of internal cooling resulting from evapotranspiration, (4) undesirable shielding of sunlight by equipment, and (5) high humidity due to evapotranspiration.

These influences are countered by cooling a heating equipment. Engineering calculations bas on climatic factors, environmental requirements f the crop, and structural factors determine the equi- ment needs and designs. A well established engi- eering and production industry supplies greenhous and associated engineering services to purchase The industry will assist prospective developers wi the details of greenhouse design, layout, and equi- ment. However, the buyer must beware. Befo asking for help from a commercial firm, the c- veloper must have some idea of what he needs a the quality he should expect. Otherwise, he m acquire equipment he does not need or that is poor constructed.

There is considerable choice among componen needed for greenhouse temperature modification a the way they can be arranged. An engineering fir can be hired to design the system, but this may be t expensive for the small developer, who more oft makes his decisions on the basis of greenhou manufacturers' or dealers' recommendations, and h own experience and knowledge. Visit other gree- house installations, and talk to fellow nurserymen get a measure of the reliability and competence local greenhouse distributors. Try to deal with distutors who carry a full line of greenhouses and quipment to assure several choices of component ombinations and prices. Ask what sizes are cheapest er square foot in each greenhouse type. Economics f design and frequency of sale of a given type or size ften can affect prices drastically. Keep notes on all ypes of houses seen, comments by users, prices, etc.

The developer should also attempt to get a basic ducation in greenhouse physics and design calcu- ation. A concise and cogent explanation of green- ouse thermodynamics, psychrometrics, and aero- ynamics can be found in the "Greenhouse climate ontrol handbook" from Acme Engineering (Augs- urger et al. 1975). It explains how some greenhouse omponents are sized through the use of various athematical formulas and rules of thumb. Other ources of information on equipment for heating and ooling greenhouses are A.S.H.R.A.E. handbooks nd publications of the National Greenhouse Manu- acturer's Association. Some understanding of the alculations for heating, cooling, and ventilating reenhouses can save the small developer much oney. He can critically review greenhouse proposals rovided by manufacturers from both a technical nd a cost approach.

The design for heating and cooling a greenhouse is ffected by what crops are to be grown at the site and n what season. A method for projecting crop growth hrough a seasonal rotation to optimize greenhouse pace utilization is described in section 5.3. This rojection can be used to relate greenhouse tem- erature requirements to the seasonal weather and to projected growing schedule, as outlined in section 5. This schedule outlines the development of the crop at a given time and gives environmental conditions needed to maintain that development. Consequently, the nurseryman can supply the designer with environmental conditions to be maintained in the greenhouse for any time of year. These factors combined with capital investment and other constraints, will allow suitable design alternatives to be assembled for the developer's consideration.

The more specific the developer can be about crop requirements for the proposed operation, the better a greenhouse designer can tailor designs to needs. If the developer has only vague ideas of what he needs or wants in terms of greenhouse environment any given time of year, the designer must always plan to meet the most demanding situation. That may be more costly than necessary.

The designs of other greenhouse components (generators, nutrient injectors, benches, etc.) are best incorporated in the original design. However, these other components usually can be changed without upsetting the basic physics of the greenhouse. Therefore, the design and selection of these parts is not as critical as the design and selection of structure, covering, heating, cooling, and ventilation.

6.12 Cooling

A type of ventilating and cooling system which takes advantage of wind and convection is illustrated in figure 6-2. The degree of temperature control depends upon house configuration, wind speed, and temperature. Natural ventilation cooling is widely used in CTS nurseries in the cool climate of the Pacific Northwest.

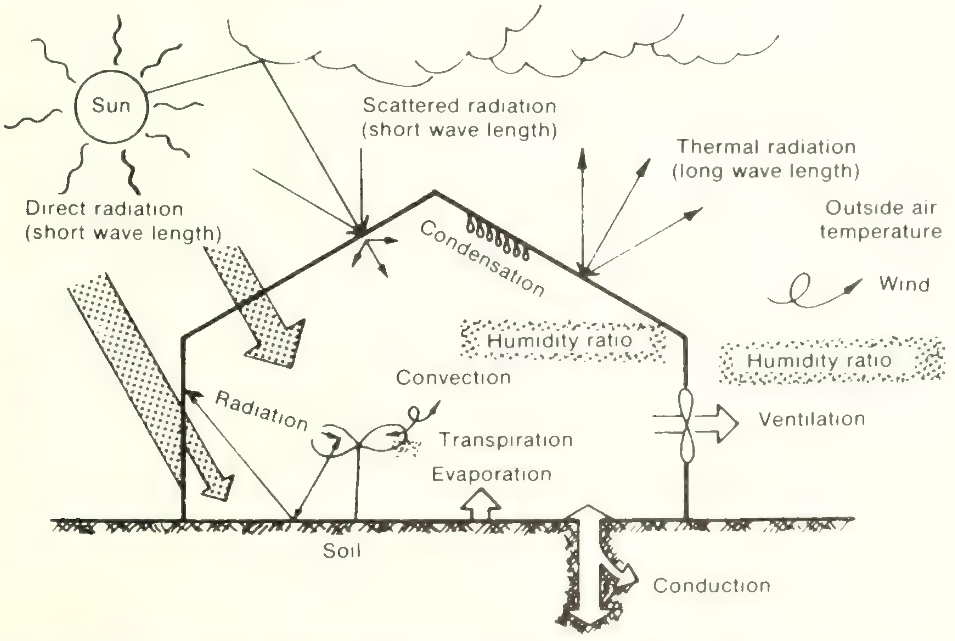


Figure 6-1.—Schematic representation of thermal environment of greenhouse (Ekblad 1973).

Exhaust fan cooling is similar in principle but provides positive control. The fans should be placed near plant level (figure 6-3) to minimize disturbance of hot air near the ceiling. These are usually sized by rule of thumb, based on air exchange rate. A widely used curve is presented in figure 6-4. Air exchange rates between three-fourths and one per minute are the most efficient. This curve is based on 50% of the incoming solar radiation being utilized for evapotranspiration. Generally, this system will maintain temperatures in a greenhouse 5° to 15° F (3-8° C) above outside dry bulb temperature.

Three types of evaporative cooling (figure 6-5) are used. The water spray may provide too much moisture and uses high pressure, and the small orifice nozzles are prone to plugging. The most popular is the fan and pad system. Pads may be of aspen excelsior, treated cardboard, or lava rock.

In addition to ventilating and evaporative cooling, various shading methods are used to reduce temperatures inside the greenhouse. Figure 6-6 illustrates some of the popular methods.

Synthetic fiber shade cloths may be stretched over the outside of a greenhouse to reduce greenhouse heating by the sun in summer. The degree of effectiveness depends on the opacity of the cloth. Shade cloths are available in grades providing shading range from 25% to 90%. An advantage of shade cloth is that solar radiation can be intercepted before it reaches the greenhouse. Studies in Arizona have shown this procedure to be an effective way to reduce greenhouse heating from solar insulation (Davis and Cole 1976). The same work revealed that placing shade cloth inside the greenhouse above the crop effectively raised greenhouse temperature although light intensities on the crop were reduce Shade cloth inside the greenhouse may also interfe with proper ventilation.

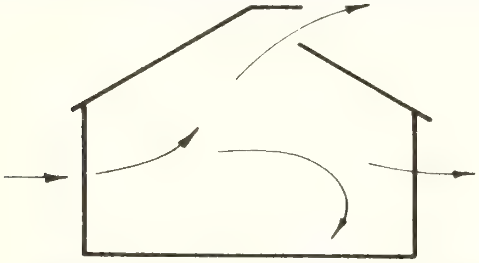


Figure 6-2.—Natural ventilation (Ekblad 1973).

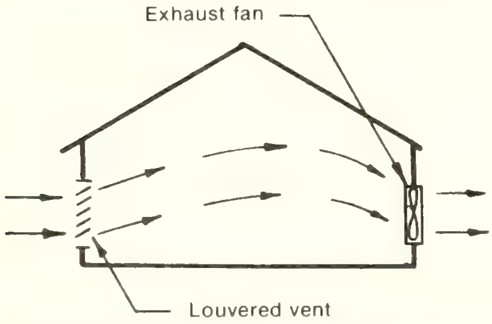


Figure 6-3.—Exhaust fan cooling (Ekblad 1973).

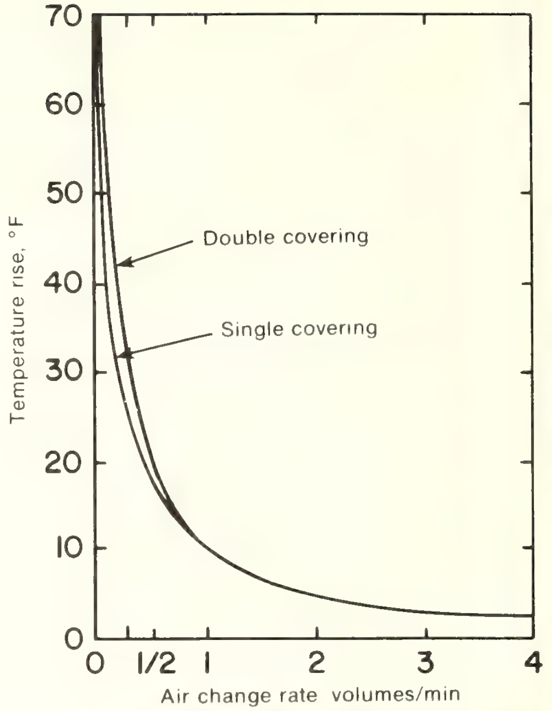


Figure 6-4.—Influence of air-exchange rate on temperatu rise in single or double plastic-covered greenhous (Ekblad 1973).

A method used in California is to replace tl plastic film with cheesecloth during the summer. Th not only provides shading but increases ventilatio This is most practical when the plastic film replaced annually.

In many parts of the country, it is comm practice to paint the outside of the greenhouse in tl summer to reduce the heat trapped in the structu and reduce the cooling load. Special greenhou "shading compounds" are available which provide translucent coating. Light or heavy coats can applied depending on how much shade is desire The paint usually weathers away, and many a designed to peel off with the first hard frost.

The advantages of such coatings are:

1. They are easy to apply.
2. Multiple coats can give different light inte sities even in different parts of the same hous
3. They are economical.

The disadvantages are:

1. They are hard to apply evenly enough

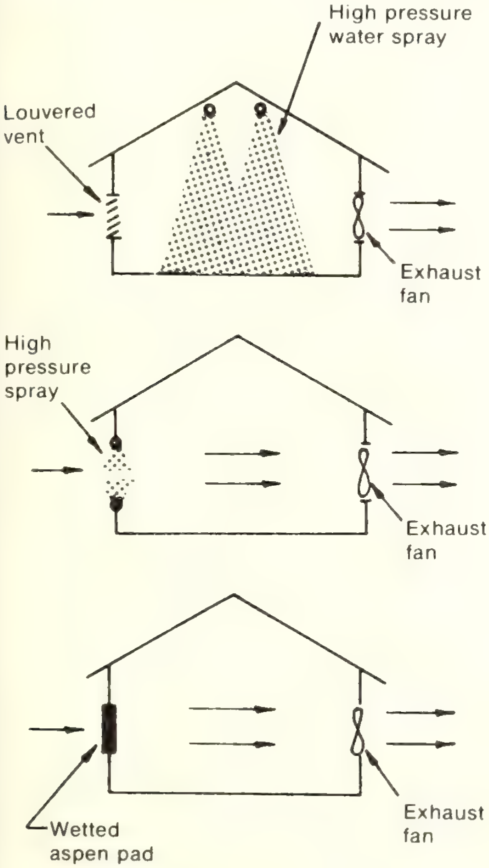
avoid variations in greenhouse light intensities.

2. Loss of paint due to rainfall may take place more rapidly than desired.
3. Collection of dirt on the paint may cause variations or increase in opacity of the greenhouse that are not wanted.
4. Light intensity cannot be conveniently increased once paint is applied.

Running water over the outside of the greenhouse an reduce internal temperatures, and can be done emporarily with a sprinkler in emergency situations. To be used over the long term, engineered systems vould require soft water and filters, and possibly ause maintenance problems. Collection of water irculated between the layers of a double wall olyethylene covered house is one way to collect olar energy (Whitcomb 1976).

.13 Heating

A common system of heating greenhouses is steam r hot water radiation using either plain or finned ubing around the house walls. A typical temperature



igure 6-5.—Three types of evaporative coolers for greenhouses (Ekblad 1973).

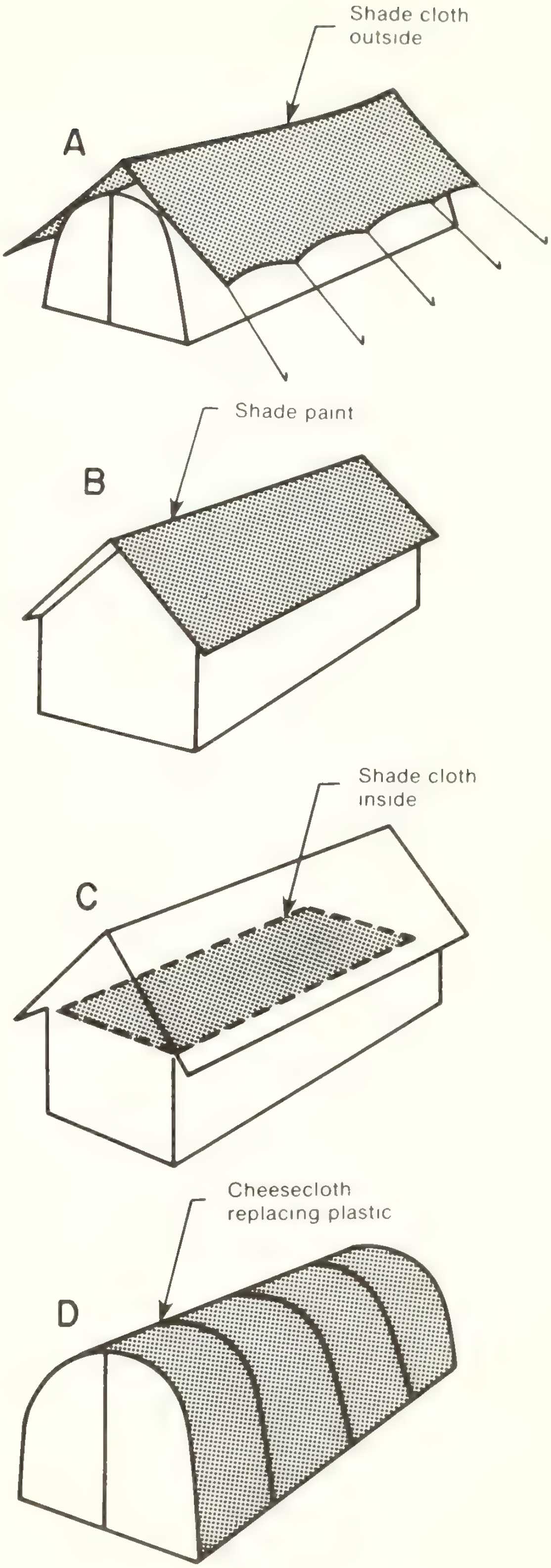


Figure 6-6.—Various methods of providing shade (Ekblad 1973).

distribution created by such a perimeter heating system is shown in figure 6-7.

This distribution can be improved by providing one-third of the total radiation uniformly across the house, either above or below the benches. An overhead circulating fan, referred to as a turbulator, is sometimes used to improve circulation. Figure 6-8 illustrates the airflow pattern expected by the manufacturer of this fan. The radiation tube heating method lends itself to large installations with a central heating plant.

Many new greenhouses, especially plastic covered ones, are heated with unit heaters. Some configurations are shown in figure 6-9. The most satisfactory are the two which incorporate an air distribution system in the form of a polytube. The polytube is a large polyethylene tube which is closed on one end and distributes air from many small holes in its side. These tubes may be used in multiple units, depending upon the size of the greenhouse. In severe climates, the addition of a cold air pickup hood at floor level reduces temperature differentials. An additional benefit of the polytube system is that it can be used to circulate air when no heat is being added, and it can be used as a mixing chamber to temper cold outside air.

The University of Kentucky has prepared nomographs for calculating heat requirements for greenhouses and estimating annual heat costs for greenhouses (Zimmerman et al. 1969).

6.14 Winter Ventilation

During hot weather, large quantities of air move through the greenhouse, either naturally or from fans, to provide cooling and ventilation. During winter, special attention must be given to ventilation to provide uniform heat, prevent high humidity, and provide gentle air movement around the plants.

In small greenhouses, ventilation and circulation may be provided by overhead fans and vents, windows, or doors. In the past several years, systems have been developed that give better results and are especially suitable for automatic controls. The major

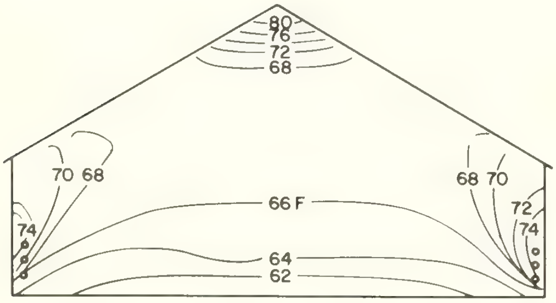


Figure 6-7.—Temperature profiles in a greenhouse heated with radiation piping along the sidewalls (Ekblad 1973).

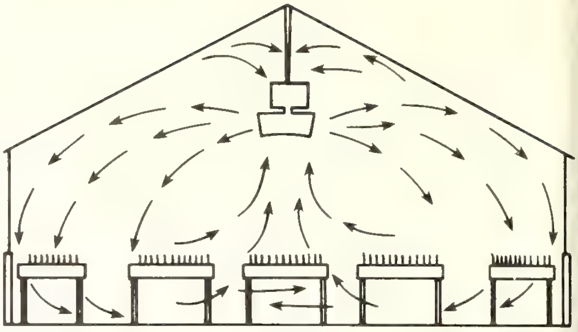


Figure 6-8.—Turbulator airflow pattern (Ekblad 1973).

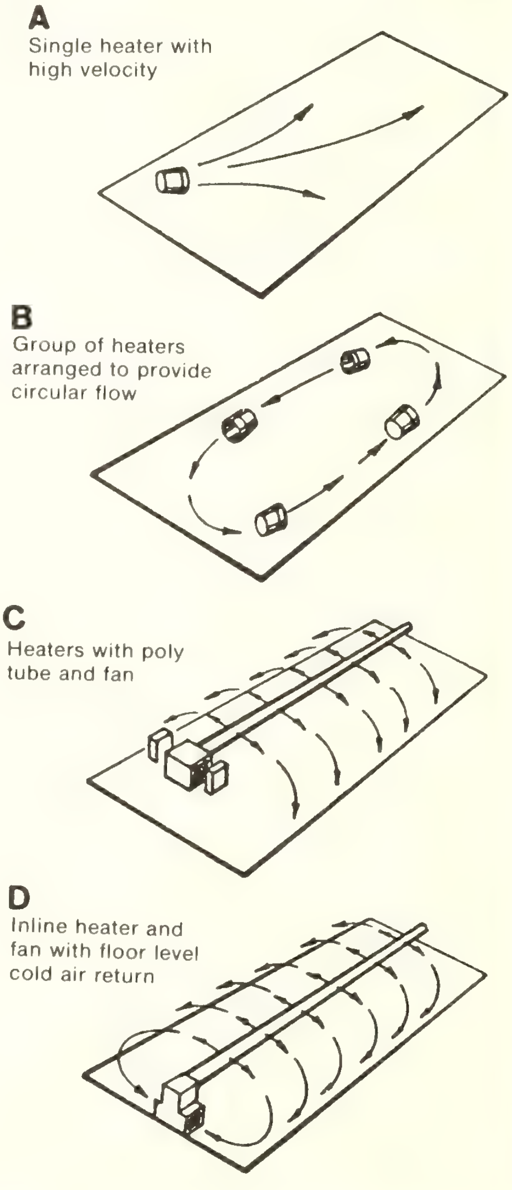
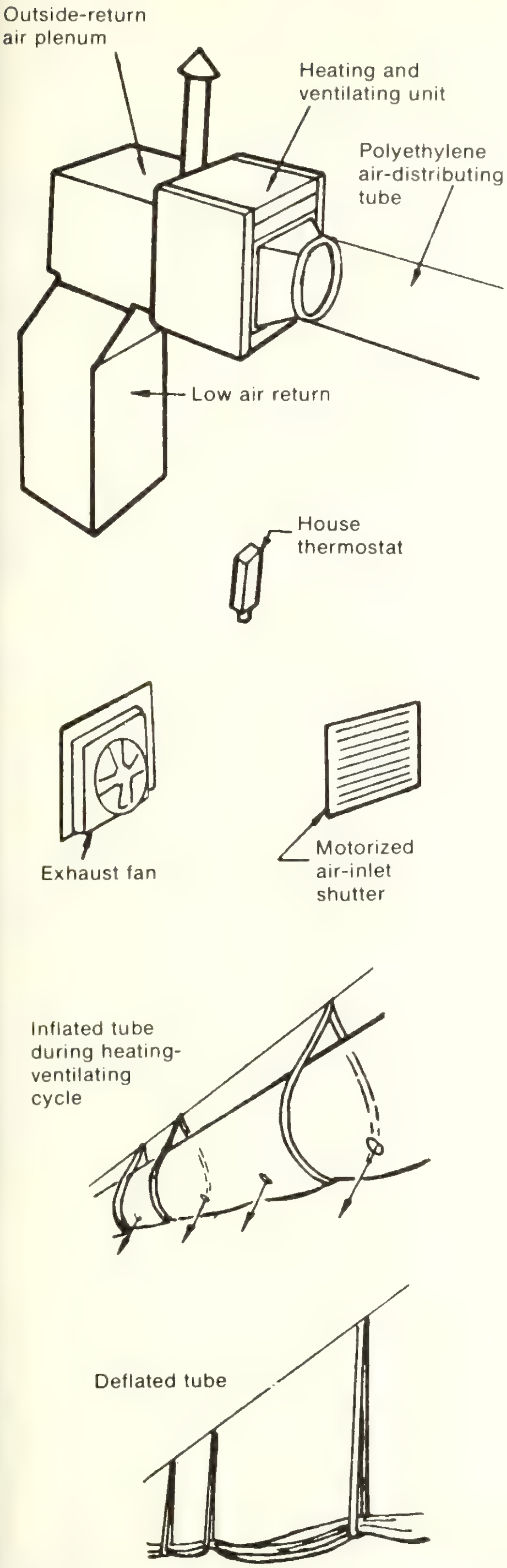

A
Single heater with high velocity
B
Group of heaters arranged to provide circular flow
C
Heaters with poly tube and fan
D
Inline heater and fan with floor level cold air return

Figure 6-9.—Arrangement of unit heaters for greenhouse (Ekblad 1973).


Outside-return air plenum
Heating and ventilating unit
Polyethylene air-distributing tube
Low air return
House thermostat
Exhaust fan
Motorized air-inlet shutter
Inflated tube during heating-ventilating cycle
Deflated tube

gure 6-10.—Components of a winter ventilation system (Ekblad 1973).

components of a typical system are shown in figure 6-10.

The air circulation fan at the entrance to the polytube is allowed to operate continuously. The outside air inlet is operated to add outside air as needed for temperature and humidity control. The exhaust fan, which may be a part of the summer cooling system, is used in conjunction with the air inlet. Several types of cycles are shown in figure 6-11.

Several companies sell packaged or specially designed control systems that can include fan and pad cooling as well as winter ventilation (fig. 6-12).

6.15 Energy Conservation for Greenhouses

The increasing cost and scarcity of traditional fuels for heating greenhouses have prompted a very active research and development effort by government and industry to reduce the energy requirements of greenhouse operations. Some authorities believe far greater heat savings are necessary, if the commercial greenhouse industry is to continue as a viable segment of the agricultural economy (White et al. 1977). Some of the more basic energy conservation hardware and construction techniques such as thermal blankets and double-walled plastic or acrylic sheeting are already commercially available. The greenhouse developer should make sure to use the latest energy saving design and equipment that is economically justified in any new greenhouses.

However, potential greenhouse energy savings are not necessarily confined to equipment. White (1977) lists the following ways to save energy:

1. Select sheltered sites that are not in frost pockets (section 4.13).
2. Manage the greenhouse to maximize space utilization and solar energy capture:
   a. Minimize overhead piping and frameworks.
   b. Use effective windbreaks to reduce conductive heat loss.
   c. Keep covering material clean.
   d. Keep the greenhouse filled with plant material.
   e. Prevent shading of the greenhouse.
3. Modifications in cultural procedure can save energy:
   a. Lower plant growing temperatures.
   b. Plant earlier in the fall or later in the spring to take advantage of more natural heat from the sun.
   c. During coldest months, concentrate on plants that tolerate lower temperatures.
   d. Discontinue growing during coldest months.
4. Heat can be conserved:
   a. Install or convert to efficient boilers, burners, or heating elements.

b. Use efficient heat distribution systems. This includes insulating supply pipes, preventing steam or water leaks, and possibly skirting benches.
c. Use high quality controls that permit little temperature fluctuation and provide uniform heat patterns.
d. Seal and insulate the greenhouse. Use thermal blankets and perimeter insulation.
e. Where possible, use alternative energy sources such as solar, waste heat, or geothermal.

Care must be exercised to assure that equipment and structural changes made to save energy are economic. Also, it appears from recent research that a number of economical and effective energy conservation developments are forthcoming (Short 1977, Jensen 1977b, Hyde 1976, McDonald 1977a, Patch 1977, McDonald et al. 1976).

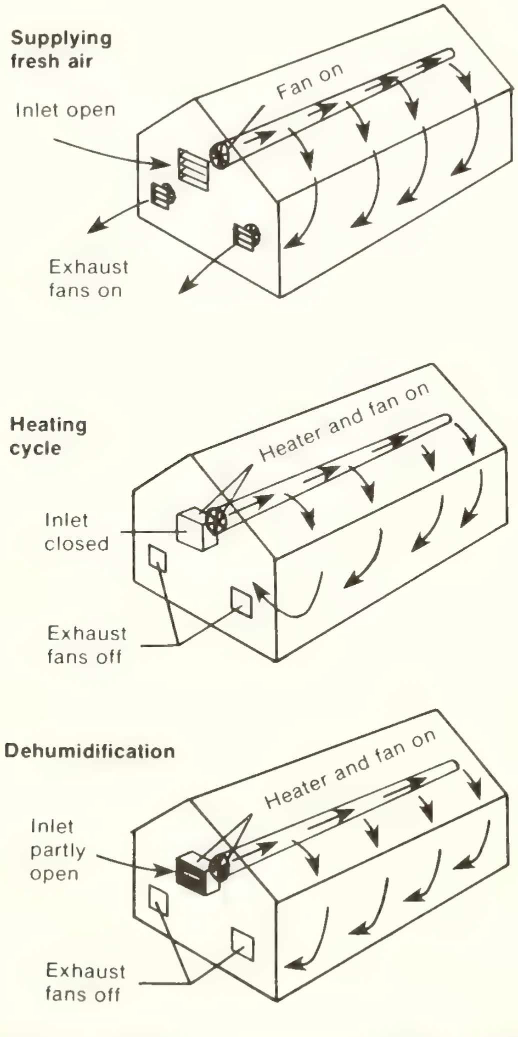


Figure 6-11.—Operation of a winter ventilation system (Ekblad 1973).

6.2 Greenhouse Lighting

The effects of light on CTS growth are discussed i section 12. Artificial light is provided to seedlings fo two purposes: (1) to increase photosynthesis and (2 to prevent dormancy.

6.21 Lamps for Photosynthesis

To provide enough light to induce effective photo synthesis is quite expensive and probably impractic in most CTS nurseries, because 7-12 kilolux ar required. Where it can be justified, the followir lamps can be used:

The Xenon arc was one of the first high intensit sources used for photosynthesis. Its spectrum ap proximates sunlight, but it is very high in infrared The light must be filtered through a water bath t make it suitable for plant growth. The arc also need a flowing water jacket for cooling the bulb, whic complicates the installation.

A quartz-iodine arc light also produces a ver "white" light and makes very good building lightin for people, but produces a lot of radiation that plant does not use efficiently.

Many fluorescent lights have a desirable spectru in that their output peaks at 575-600 nm, and there no output in the infrared. However, it is difficult achieve intensities high enough to be effective, ar the relatively large fixtures create a great deal shade, which reduces the efficiency of sunlight use.

Incandescent light is also suitable for photosy thesis but is not very efficient, because such a lar proportion of its output is in the infrared. It generally used in conjunction with fluorescent ligh to more nearly match the solar spectrum.

Probably the best source is the sodium arc. I output peaks sharply at 590 nm. There is very litt ultraviolet, and acceptable levels of infrar produced. It is an intense light, so, the fixtures can spaced widely enough to avoid blocking mu sunlight.

6.22 Lamps for Prevention of Dormancy

To prevent tree seedlings from becoming dorma prematurely, artificial lighting to prolong the phot period is often necessary. The biology of this ph nomenon is discussed in section 12. Three methods a used to prevent dormancy induction: photoperi extension, night break, and cyclic lighting. Phot period can be extended by continuous lighting 4 to hours after sunset or before sunrise. Night bre lighting employs 2- to 5-hour interruptions duri the dark period. Cyclic lighting is brief interruptio of light repeated every 5 to 30 minutes througho the dark period. This may require lighting only 2%

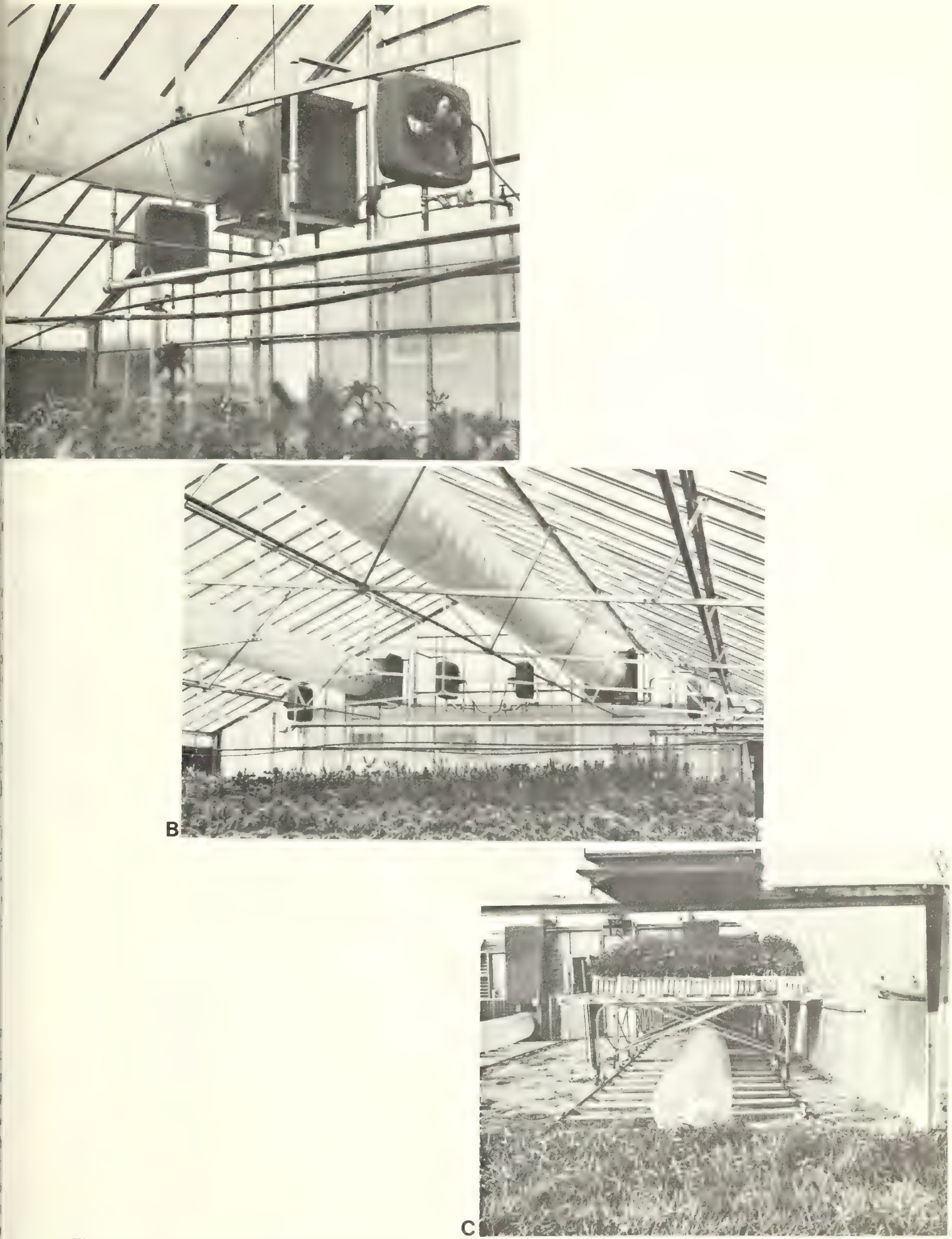


Figure 6-12.—Typical ventilating and heating system installed overhead (A and B) (courtesy of Acme Engineering and Manufacturing Corp.), or under benches (C).

10% of the time. Interrupting the dark period prevents cessation of stem elongation until adequate height growth is achieved. With southern genotypes, this practice may only be for "insurance" in summer. With northern genotypes, high elevation strains, or any time of the year other than early summer, photoperiod lengthening is essential. In fully controlled greenhouses, the interrupted dark cycle should always be employed during the height growth phase. The only cases where interrupted night might not be desirable are in the raising of ecotypes native to climates with long growing seasons. For instance, Owston[1] reports that coastal Douglas-fir and Western redcedar become tall and spindly under an interrupted night.

For interrupted night techniques to be fully effective, other factors in tree seedling's environment, such as temperature, humidity, water, and mineral nutrition, should be optimal. In CTS operations involving only control of watering and fertilization with little control of air temperature fluctuations, interrupted night is of less value.

Light intensity for phytochrome excitation need only be in the 40-foot-candle (430-lux) range.

Some of the factors to consider in selecting light source, intensity, and arrangement are: uniformity of light distribution, desired spectral energy distribution (SED), protection from humidity and water drops, light efficiency, initial cost, replacement cost, and minimum shading in daytime.

Three types of light sources are used: incandescent, fluorescent, and high-intensity discharge. The incandescent lamp consists of a heated filament enclosed in vacuum or surrounded by a gas such as nitrogen, argon, or halogen. The SED is basically dependent on the temperature of the filament, although the SED may be altered through the use of filters.

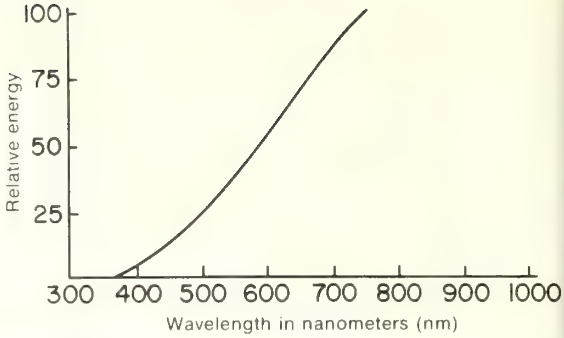


Figure 6-13.—Spectral energy distribution of a typical incandescent lamp (Bickford and Dunn 1972).

Incandescent lamps provide the desired spectra qualities, are cheap to install, and can be turned o and off without loss of bulb life. They are not as economical to operate as some other types of lamps, bu their other characteristics (cost, spectral qualitie make them most advantageous. Figure 6-13 show the SED of a typical incandescent lamp. Many type of incandescent lamps are available (fig. 6-14), an no ballasts are required. Some disadvantages ar low efficiency, point source of light (needs reflector needs protection from water, and short life.

The standard incandescent bulb requires an external reflector to distribute light more uniformly. Th reflector also provides protection from drippin water but casts unwanted shadows. Special types o the internal reflector (PAR and R) lamps ar available with dichroic reflectors. They reflect th useful light forward and transmit infrared throug the back of the reflector. The SED of a 150-watt PA 38 lamp is shown in figure 6-15. Another speci lamp that has been widely used in greenhouse applications is the pear-shaped, straight-necked lam with internal reflector.

Most CTS greenhouse operators use incandesce lamps in a fixed arrangement as in figure 6-16. A

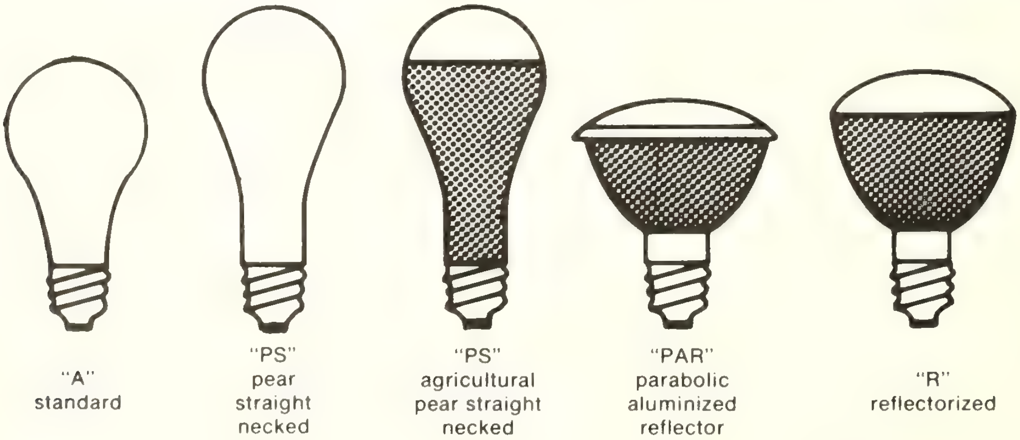


Figure 6-14.—Bulb shapes of incandescent lamps for photoperiod control (Ekblad 1973).

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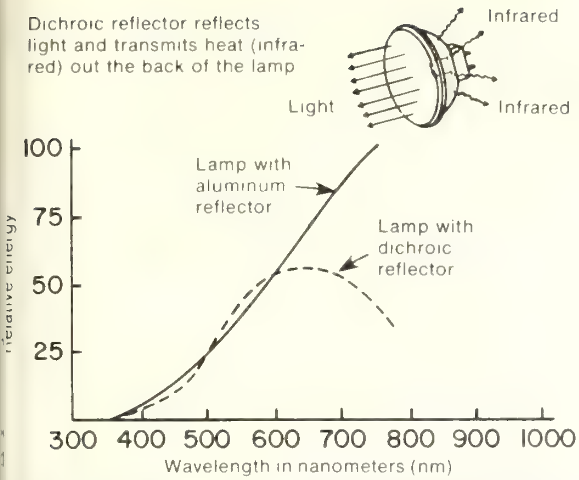
[1] *Personal communication with Dr. Peyton W. Owston, Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg., June 1978.*



igure 6-15.—Spectral energy distribution (SED) of a dichroic reflector compared to the same lamp with an aluminum reflector (Bickford and Dunn 1972).

electrical time clock switch turns the lamps on and off at prescribed intervals (see section 12 for interrupted night recommendations on frequency and ntensity). Usually, in smaller greenhouses, all lights come on at once. In many larger installations, only part of the house comes on, then that part goes off, and another comes on. This sequencing reduces the otal electrical demand and allows lighter duty ervice to be used.

The fluorescent lamp produces light by the action of radiation from a low pressure mercury arc on a phosphor coating of the inner surface of a glass tube. The fluorescent lamp requires a more complex lectric circuit, including a somewhat bulky ballast, and lamp life is shortened if it is cycled on and off requently. Fluorescent lamps are available with widely different SED's. Figure 6-17 shows the SED of one type of cool white fluorescent lamp. The sharp peaks are typical of most fluorescent lamps. A special fluorescent lamp for plants that produces nore light in the 600-700 nm band is available. The nitial installation cost of fluorescent lamps is twice hat of incandescent, but they are four times as efficient in producing visible light and may last up to 2 times longer, provided they are not cycled on and off frequently. Also, the fluorescent is a line source of ight which eliminates shadows as well as hot-spots irectly beneath the lamp.

The objection that fluorescent lamps provide too nuch daytime shading can be reduced by special greenhouse fixtures that include remote ballasting and tandem arrangement of lamps. A special greenhouse lighting fixture is shown in figure 6-18. Waterproof fixtures with covered lamps are usually recommended for greenhouses.

High-intensity discharge (HID) lamps include nercury, metal-halide, and sodium lamps. Of these, only the metal-halide and sodium arc have been used for photoperiod lighting. The SED of the sodium and metal-halide are shown in figures 6-19 and 6-20, respectively. They are not suitable for cyclic lighting, because they require 5 minutes to start and cannot be conveniently used in short-duty cycles.

The important values are the energy available at or near 660 and 730 nm, not total visible light. Table 6-1 shows the energy output per watt in four bands for eight selected lamps. For photoperiod control, the two bands of interest are 600-700 and 700-800 nm.

6.23 Lamp Arrangement

There are three basic ways to arrange lamps.

Fixed array.—Lights may be installed overhead in a fixed array. Since those used for dormancy prevention only have to be on for a small fraction of the time, the electrical entrance need only be large enough to handle 1/15 of the lights at one time (section 6.53). (This could be 1/30 if species would

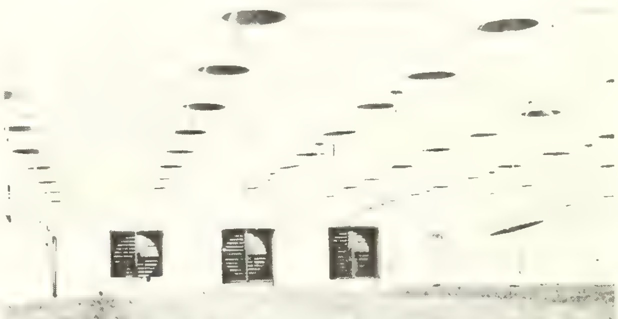


Figure 6-16.—Typical installations of incandescent lights to lengthen photoperiod (A) in a wide gabled greenhouse and (B) in a 27-foot (8-m) wide quonset.

never be grown that required light 6% of the time instead of 3%). A light source is needed that provides red light efficiently and can be turned on and off quickly and repeatedly. Most arc lights require lengthy warm up times and cannot be turned on rapidly. Fluorescent lights can be turned on and off rapidly, but this wears them out quickly. Incandescent lights are usually the best choice, because they provide satisfactory amounts of red light and can be repeatedly turned on and off without damage. When using incandescent lights, figure 86 watts per square meter of installed lighting, unless it is known in advance that the species to be grown respond adequately to less light. Lights should be 1.5-2.5 m above the seedlings. Use larger bulb sizes and fewer fixtures to minimize cost and maximize efficiency, consistent with keeping minimum light intensities above 400 lux. Arrangement of lamps for photosynethetic lighting must be a fixed array, wired to all be on at once, with lamps placed close enough together to provide the required intensity at seedling height.

Movable lights.—Another system is to leave the lights on continuously, but mount them on a moving boom. This way there is more choice of light sources, and a few intense sources can do the same job as a

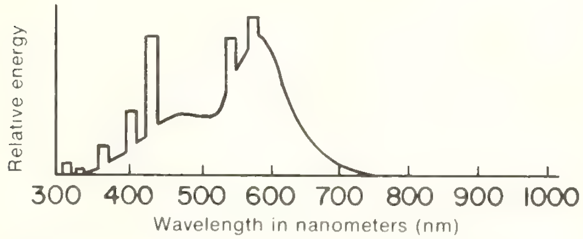


Figure 6-17.—Spectral energy distribution for a typical cool white fluorescent lamp (Bickford and Dunn 1972).

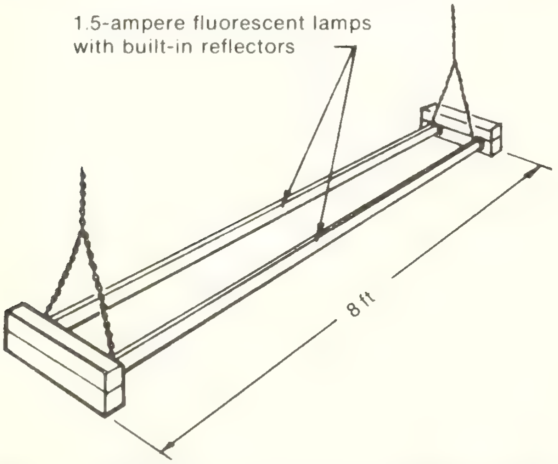


Figure 6-18.—Special greenhouse lighting fixture to minimize shading (Ekblad 1973).

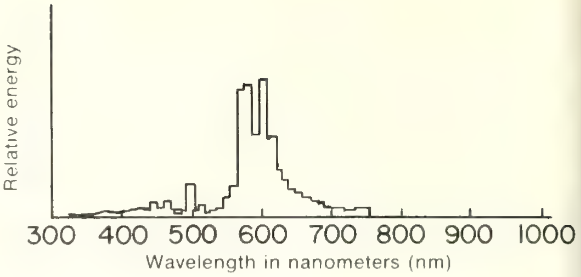


Figure 6-19.—Spectral energy distribution of 400-watt high-pressure sodium discharge lamp (Bickford and Dunn 1972).

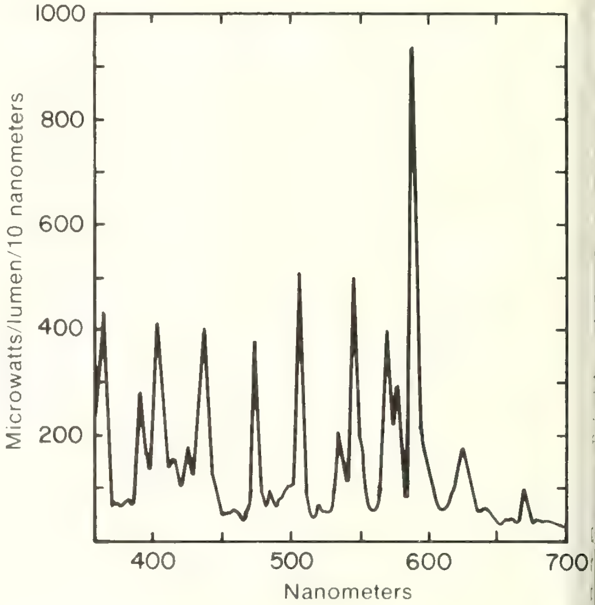


Figure 6-20.—Spectral energy distribution of a typica metal-halide lamp (Bickford and Dunn 1972).

much larger fixed array. Probably the most efficier source would be the sodium arc (Arnott 1974, 1976 The only requirement would be that the boom mak at least one round trip every 30 minutes. The movir boom system is a tempting choice for a greenhou that is equipped with a moving boom waterir system. In some installations, the lights and the wat have been placed on the same boom.

This system has its own problems, however. If th boom should malfunction, the greenhouse woul lose both its water and lights. It is best to keep much of the electrical machinery out of the greei house as possible. A watering boom can be cab driven by a remote motor; but there is no way avoid delivering electricity to a lighting boor Nutrient solution is very corrosive to electric machinery and fixtures, which must be careful waterproofed and preferably kept out of contact wi nutrient solutions.

Table 6-1.—Energy output of selected lamps (Ekblad 1973).

			Visible Output Milliwatts					Total
Lamp	Lamp watts	Total[2] watts	Lumens	400-500 (nm) watts	500-600 (nm) watts	600-700 (nm) watts	Visible total watts	IR far red 700-800 (nm) watts
Incandescent (100A)	100	100	1,750	0.8	2.2	3.9	6.9	4
Fluorescent CW 40 W (F 40CW)	40	50	3,200	2.7	4.5	2	9.2	—
Fluorescent Special Plant Lamp 40W	40	50	—	2.2	2	3.2	7.4	0.7
Fluorescent CW 1,500 MA (F 96T12/CW)	215	235	15,000	12.7	21.2	9.4	43	—
Fluorescent 1,500 MA Special Plant lamp	215	335	—	10.3	9.4	15	35	3.3
Fluorescent CW 1,500 + 100 W Incandescent	315	335	16,750	13.5	23.4	13.3	50	4
Mercury Phospher	400	425	20,000	11.6	28.4	18.3	58	—
Metal-Halide	400	425	31,000	26.2	50	12.1	88	[3]4
High-Pressure Sodium	400	425	42,000	10.3	55	39	105	[3]4

[1]Typical values from manufacturer's data. IES handbook data and other publisher data.
[2]Includes ballast or auxiliary input.
[3]Estimated.

Parabolic mirror.—Another possible way to achieve the same thing would be to use a fixed high-ntensity source and move the light across the house with a rotating or oscillating parabolic mirror. At east two lights per house should be used to eliminate shadows and provide redundancy in case one fails. To the authors' knowledge this system has not been ried yet.

It is suggested that the greenhouse designer work closely with a plant expert most knowledgeable about the species to be grown. The size, location, and arrangement of luminaires can be selected using standard lighting calculations and tables given in the Illuminating Engineering Society Handbook (Ekblad 1973). When scaling from a growth chamber or small greenhouse to a large greenhouse, do not extrapolate by fixtures, lights, or watts per unit area. The edge effects of rectangular or small areas can introduce a large error. The requirements for each house should be calculated by an engineer based on spectral energy distribution required.

6.3 Carbon Dioxide Control

Carbon dioxide is the source of carbon for plants. During the night, plants respire and release CO_2. This may cause a rise in CO_2 concentration in the air to 400 parts per million (ppm) or more. However, as soon as the day begins and plants start using CO_2, the concentration drops to that of the outside air (about 325 ppm). If the house is closed during winter days with only two air changes per hour or less, the concentration often drops below 200 ppm and limits growth (Holley 1965). This situation is alleviated in the summer when air changes equivalent to one greenhouse volume per minute are required for ventilation. Good circulation of air is also helpful in making CO_2 available at the plant surface. An airflow rate of 100 feet per minute (30 m/min) has been found to be equivalent to 50% enrichment in CO_2. These are design factors that should be considered.

CO_2 may also be added artificially. Sources of CO_2 are: compressed CO_2 gas, dry ice, burning fuels, and soil organisms. Each of these sources has been used, but the most practical commercial method is to burn organic fuels.

Some factors to be considered in using burners for CO_2 production are: (1) the house must be closed, (2) considerable heat is added by the burner, (3) gases should be free of toxic byproducts, (4) CO_2 should not be added at night, (5) water is a combustion product, and (6) air for combustion must be provided.

Most commercial greenhouses use ventilation or evaporation for cooling. Both systems exhaust about one volume of greenhouse air per minute, making it impractical to add CO_2. Closed circuit cooling systems are very expensive. However, CO_2 can be added during the winter, when there is little ventilation. In the early morning and late afternoon, when cooling is not required, CO_2 may be added. Such additions are beneficial but not as efficient as midday treatments (Pettibone et al. 1970). Most plants are able to tolerate higher temperatures with increased CO_2.

The most critical plant toxicants associated with CO_2 enrichment and their maximum allowable values are as follows:

SO_2—0.2 ppm
C_2H_4—0.05 ppm
O_3—0.2 ppm
NO_2—20 ppm
NH_3—10 ppm
HCHO—0.7 ppm
CO—500 ppm

Certain compounds, such as carbon monoxide (CO) and ethylene (C_2H_4) are associated with incomplete combustion. Others are a result of contamination of the fuel, the most important of which are oxides of sulphur (Kretchman and Howlett 1970). The following fuels are suggested for CO_2 generation in tomato greenhouses because of their low sulfur content:

kerosene — 0.02% sulphur
propane — 10 grains sulphur per 100 cubic feet (230 mg/m^3)
natural gas — 3.5 grains sulphur per 100 cubic feet (80 mg/m^3) (Kretchman and Howlett 1970).

Complete combustion of natural gas and propane requires air and produces CO_2 and water in the following proportions by weight:

	Air required	CO_2 produced	H_2O produced
Natural gas (1.0)	17	2.7	2.3
propane (1.0)	16	3.0	1.6

Other hydrocarbons are similar (Sheldrake 1964).

Combustion produces from 8,000 to 10,000 Btu per pound (4,400-5,500 Kcal/kg) of fuel, depending upon fuels and burner efficiencies. Propane is the best fuel, because it has less variation in composition than other fuels. Fuels of low quality may produce too much sulphur dioxide, ethylene, or carbon monoxide. These combustion byproducts are harmful to people and plants. Kerosene generators shoul be avoided, because they are more expensive an more difficult to operate and maintain than ga burners.

Three commercial types of CO_2 generators ar shown in figures 6-21, 6-22, and 6-23. Each burne comes with instructions for installation an operation. Calibration of burners (how much CO_2 t generate) depends on the leakage rate of air from th greenhouse when its ventilation system is no operating. Pounds of CO_2 required can be estimate by the following method.

Carbon dioxide occupies 8.72 cubic feet per poun at 60° F (10°C). Therefore, to estimate the pounds o CO_2 required:

$$\text{LB } CO_2/\text{hr} = \frac{\text{house volume (ft}^3)}{8.72} \times \frac{\text{concentration (ppm)}}{1{,}000{,}000} \times \frac{\text{air changes}}{\text{hr}}$$

or:

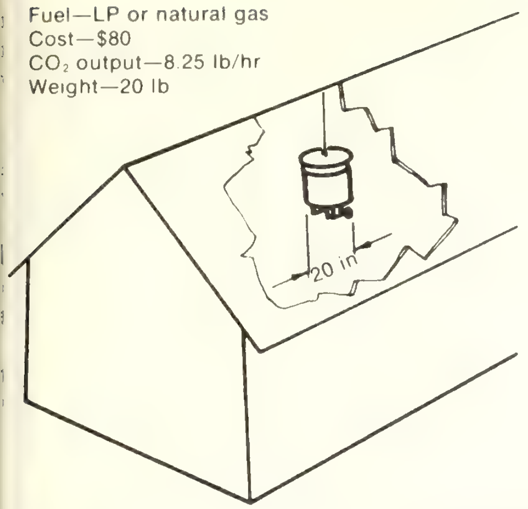
$$\text{kg } CO_2/\text{hr} = \frac{\text{house volume (m}^3)}{3.27} \times \frac{\text{concentration (ppm)}}{1{,}000{,}000} \times \frac{\text{air changes}}{\text{hr}}$$

Once the flow rate of CO_2 has been regulated for particular house, a timer switch can be used to tur the generator on and off. The timer will have to b adjusted seasonally. Switches operated by a solar cel are also available. More complex systems that sens CO_2 levels and control the generator are availabl but are not generally used in commercial greenhouse because of cost and complexity. They are generall necessary for research purposes only. Since addin carbon dioxide to the air substantially increase growth rate and costs little, it is usually a good investment in fully controlled CTS greenhouses.

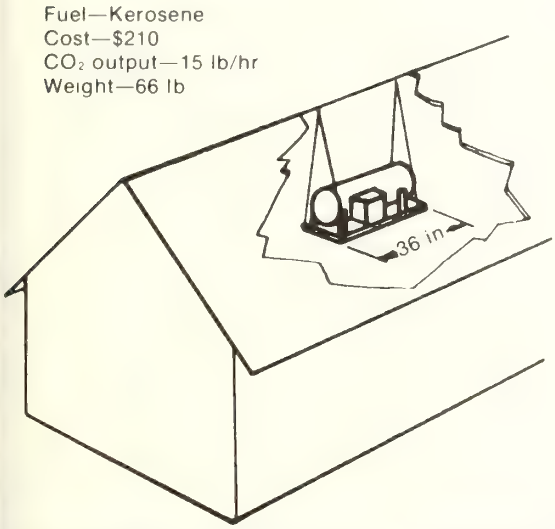
6.4 Watering and Fertilizing

Figures 6-24, 6-25, 6-26, 6-27, and 6-28 illustrat four types of commercial watering units. The mai problem with the fixed overhead, rotating, oscillating, and spray stake sprinklers is lack of unifor coverage. A second problem is accumulation o moisture on nozzles or other parts of the system tha drips on the foliage. A well designed fixed irrigatio system minimizes these problems forever.

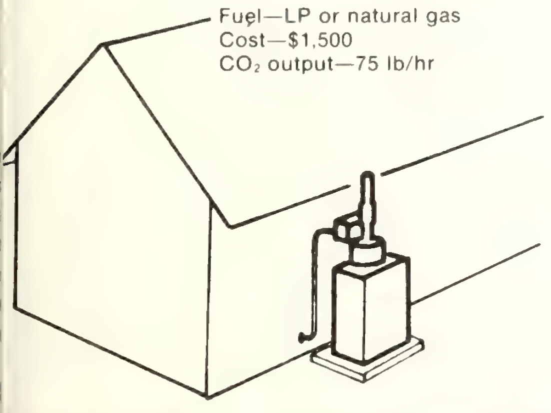
The overhead traveling boom sprinkler (fig. 6-28 has the most potential for uniform coverage. It is als the most expensive, approximately $1,500 per unit.



igure 6-21.—Inside ceiling mounted gas CO_2 generator (Ekblad 1973).



gure 6-22.—Inside ceiling mounted kerosene CO_2 generator (Ekblad 1973).



igure 6-23.—Outside gas fired CO_2 generator (Ekblad 1973).

Distribution of water should be reasonably uniform. At each irrigation, especially when fertilizing, all containers are watered to full saturation. Because excess water flows through the containers, perfectly uniform application by the irrigation system is not necessary, but uniformity is desirable to shorten the irrigation period. The shorter the irrigation, the shorter time the foliage is wet, and the sooner greenhouse humidity drops from 100%, assuming adequate ventilation. This reduces the opportunity for fungal infection.

Droplet size generated by irrigation nozzles should be small enough to avoid damaging young seedlings or washing out pot mix, but large enough to allow a short irrigation period.

Fixed irrigation systems are common. They are frequently expensive to install, but mostly trouble-free in operation. Such systems are usually manually operated or operated with electric timers linked to electric solenoid valves. Usually, in large greenhouses, only part of the house, or one of several smaller greenhouses in a complex, is irrigated at a time. This sequencing of irrigation reduces water demand peaks and allows the use of smaller pipe in the water system. Most growers use fixed systems. In some cases, travelling boom sprinklers are used. These devices move back and forth over the benches of trees watering them each time they pass. Some of the advantages of the travelling boom are:

1. Properly operated, it will provide uniformity of application no fixed system can match.
2. The irrigation equipment is out of the way when not in use.

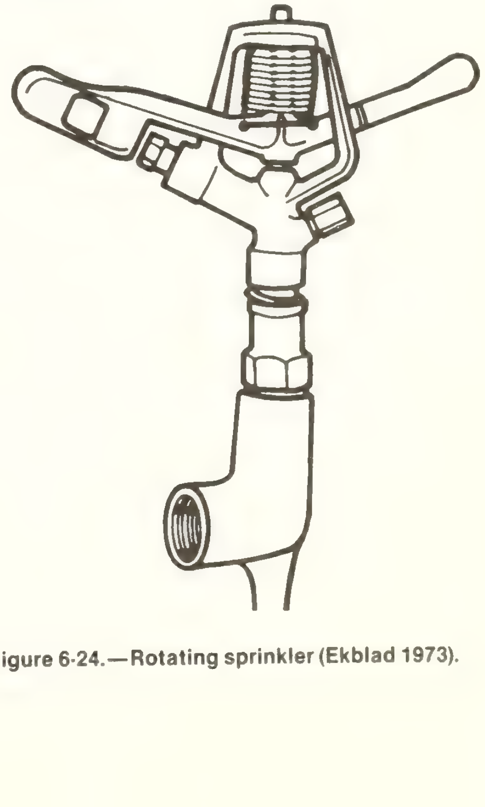


Figure 6-24.—Rotating sprinkler (Ekblad 1973).

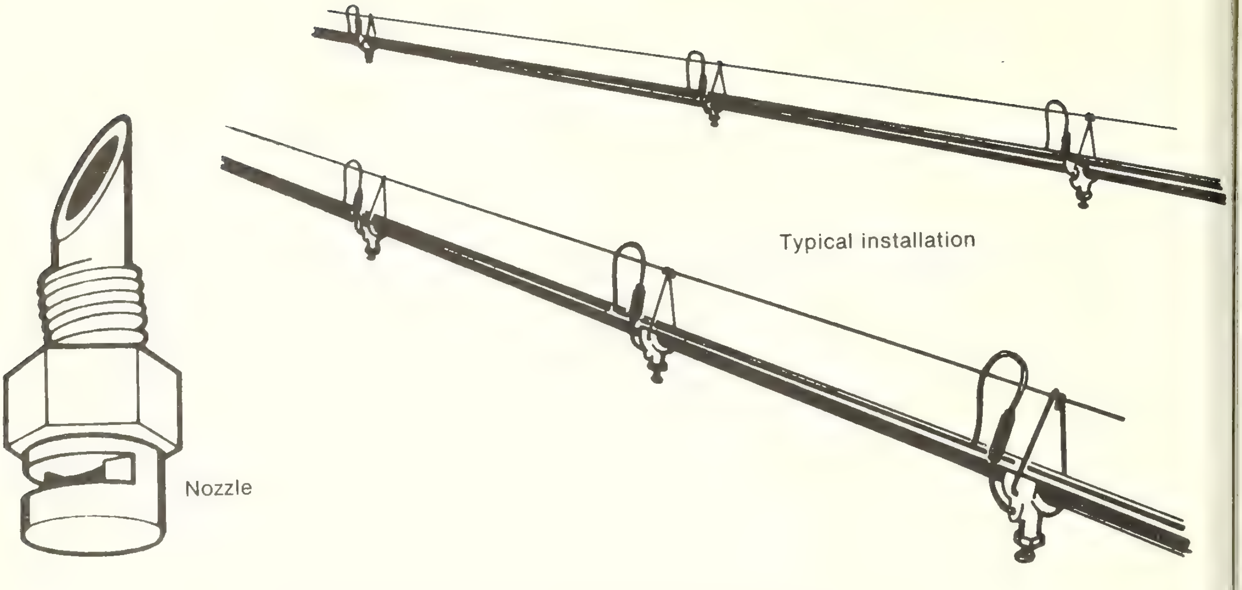


Figure 6-25.—Fixed overhead spray nozzle (Ekblad 1973).

3. Less initial investment in labor may be needed to install, but cost of the parts and material may be about the same as a fixed system. A moving boom also operates on a smaller water flow.

Some of the disadvantages are:

1. Any moving piece of equipment is prone to breakdown; travelling boom systems are often finicky and sometimes hard to operate.
2. The boom must be monitored while in operation in case of a malfunction.

Some fixed systems drip. When an improperly designed fixed overhead system is turned off, the residual water in the pipes will run out the lowest nozzles. Losses occur in trees below such drip points. There are several ways to counter this:

1. Design the system to irrigate with water supplied from below the benches or the sidewalls of the house. Of course the wat supply line may then be in the way.
2. Draw the water from the top of the overhea pipe (fig. 6-25).
3. Quickly empty the overhead pipe of residu water by putting automatic drain valves in it a regular intervals or at each end.
4. If sprinkler heads must be hung from nipple connected vertically to the main line, keep th nipple length as short as possible.
5. Run a line or string from the nozzle down to th bench surface between containers.
6. A combination of the above.

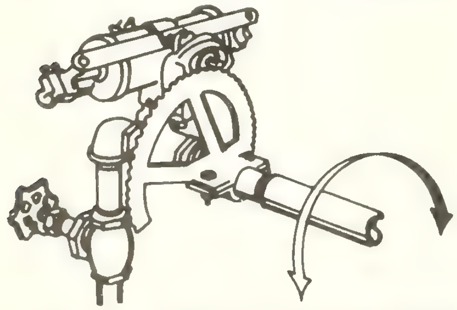


Figure 6-26.—Oscillating sprinkler (Ekblad 1973).

As mentioned in section 4.15, 0.4 to 0.5 gallons p hour per square foot (16-20 l/h/m^2) of greenhous space will saturate 8-inch (20-cm) deep containe rapidly enough to prevent foliage from being wet to long. This same guide can be used for choosin nozzle orifice size.

On the West Coast, where water sources are ver pure and salt buildup in the container is not problem, watering can be much lighter. Hahr reports that 0.1 to 0.2 gallons delivered in 30 to 8 minutes is satisfactory. He also reports that, unde high humidity conditions, the foliage never complet dries on large seedlings, even when watered onl once a week. In this case, rapid watering is n important. Foliage rinsing is not necessary, becaus the foliage does not dry and there is little opportunit for salt burn. However, constantly wet foliage is th main cause of the Botrytis disease which is commo in West Coast nurseries.

[2] *Personal communication with Phillip Hahn, Georgia Pacific Corp., Eugene, Oreg., June 1978.*

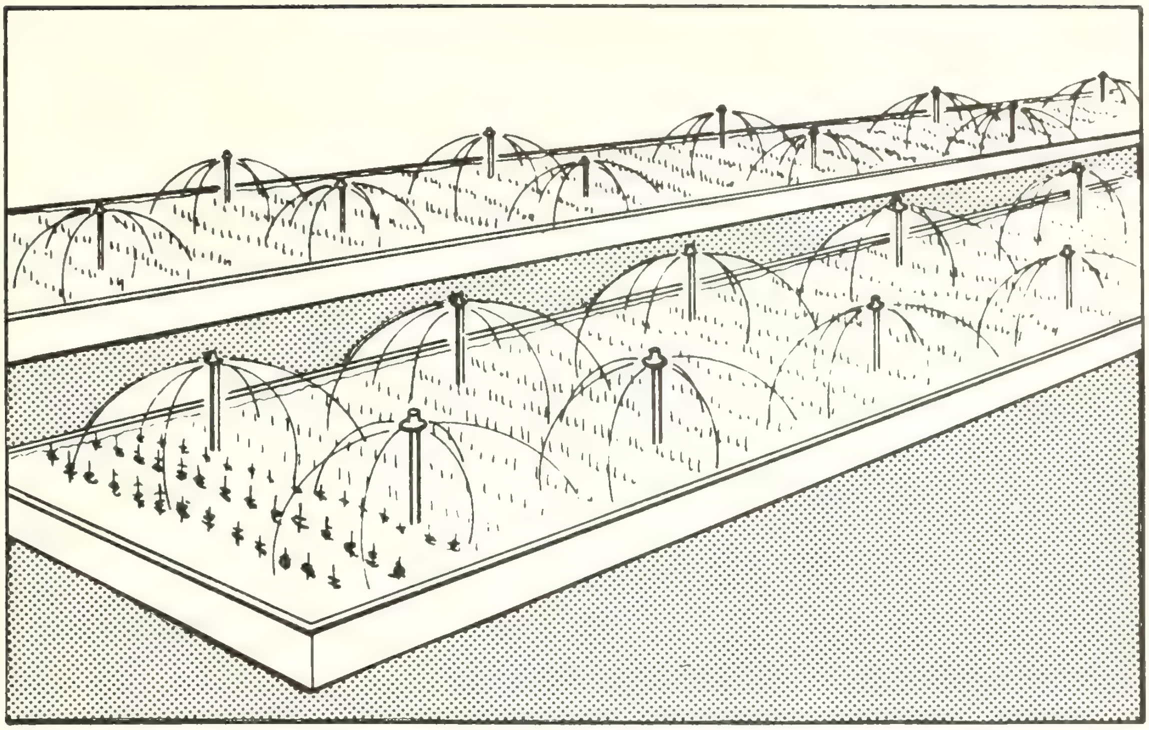


Figure 6-27.—Spray stake watering system (Ekblad 1973).

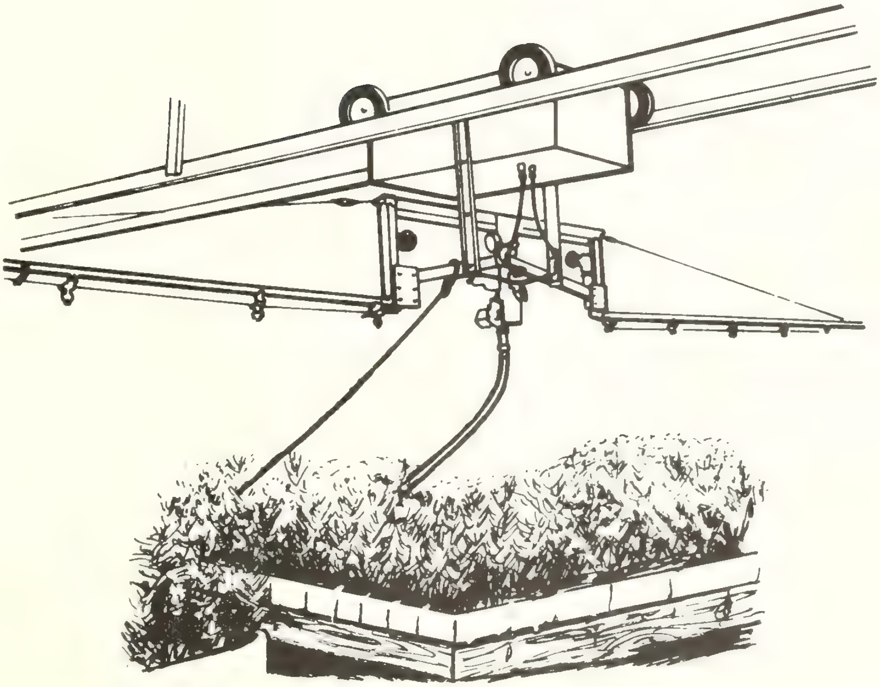


Figure 6-28.—Overhead traveling sprinkler (Creepy-crawler: Master Grower, Hatcher Sales Co.) (Ekblad 1973).

For CTS growing, irrigation water normally has to be adjusted to a slightly acid condition. This is done by acidifying the water before it enters the greenhouse irrigation system. At the same time, fertilizer solutions may be injected into the irrigation water. Such solutions corrode metal irrigation pipes, nozzles, and any other metal greenhouse hardware. This not only shortens the lifetime and increases maintenance on the system, but there is a possibility that the plants could receive toxic levels of copper or zinc. Therefore, any irrigation piping beyond the nutrient injectors should be plastic (PVC). Nozzles should be plastic or corrosion-resistant metal. If the irrigation solution is sprayed on the structural framework of the greenhouse, this framework should be aluminum, not galvanized steel. The irrigation system should be briefly flushed with plain water following a fertilizer application to wash the irrigation system, the greenhouse framework, and often the foliage. Trees should not be grown in spots where irrigation water chronically drips from the greenhouse frame. This will damage the trees and may cause localized zinc toxicity, if the frame is galvanized metal.

Nutrient injectors.—Several types of nutrient feeders are available commercially. The four basic types available for adding nutrients to the water are: suction, injection, electric, and ratio feeders. The suction feeder is attached to the suction side of the pump and an electrically timed solenoid allows chemicals to be added at a fixed rate. The injector feeder is operated by connecting a tube to the discharge of the pump, and the solution is introduced by pressure through a needle valve (fig. 6-29). The electrically driven feeder is an adjustable positive displacement pump. The motor is connected to the pressure switch of the pump and operates continuously when the switch is closed.

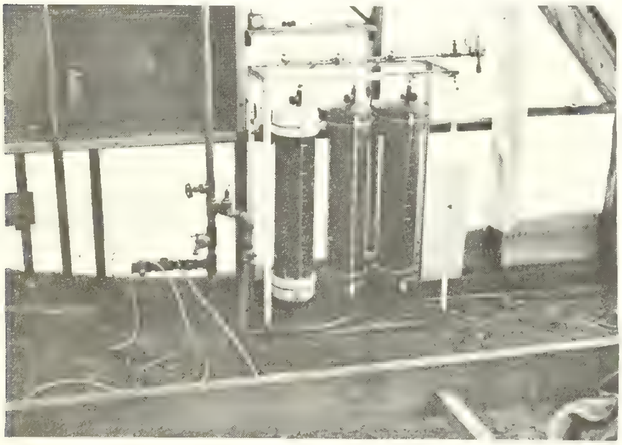


Figure 6-29.—Air pressure driven injection feeder.

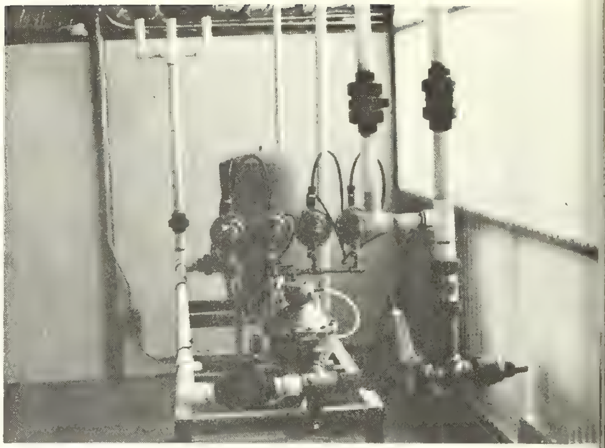


Figure 6-30.—Water driven proportional nutrient injector.

Proportional feeders are frequently used. These ar positive displacement pumps operated by flowin water (fig. 6-30).

For CTS operations, the selected injection shoul be capable of injecting nutrient solutions into th greenhouse irrigation water at a proportion of abou 200:1. Proportions of more than 400:1 will requir the nutrient solution be so highly concentrated tha chemicals will tend to precipitate out of solution Proportions lower than 100:1 will require an undul large tank of nutrient concentrate solution. The rati must be accurate, but extreme accuracy is unnecessary except where the irrigation water must b acidified to alter its pH or when pesticides are adde through the injector. In such instances, variations i injection rates are not desirable. Most injectors o the market, properly installed and calibrated, shoul be accurate enough. Water operated proportiona feeders are probably the easiest to keep accurate however. The injection rate of any injector should b monitored and adjusted as necessary to maintai reasonable accuracy. A simple effective monitorin method is to install a corrosion-resistant flow mete on the irrigation line and observe the rate of flow an the time it takes to inject a known amount of nutrien concentrate.

In some instances, two to four separate nutrien concentrate solutions must be prepared, because th chemicals in one are not compatible with those i another. These solutions can be injected either all a the same time with more than one injector or on after the other using one injector. The first procedur is preferable, because some of the first solution wil leach out of the containers while the second is bein applied.

If acidic nutrient concentrates are to be injected injectors with plastic, rubber, or stainless steel parts should be used. Injectors constructed of brass shoulc be avoided. Acids in the nutrient solution car

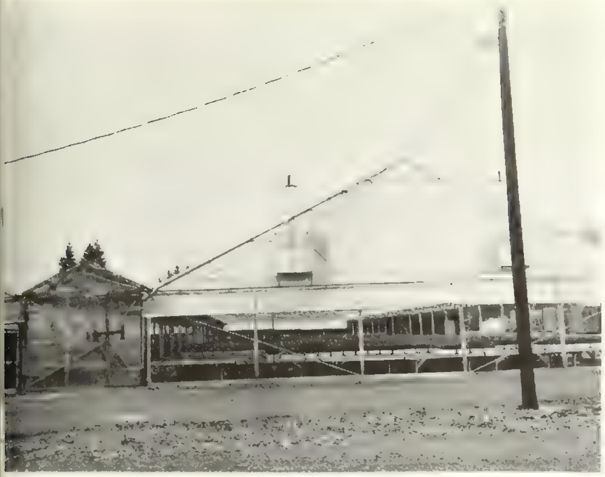


Figure 6-31.—A typical semicontrolled greenhouse.

corrode the brass causing excess copper and zinc ions in the irrigation water. The same applies to nozzle heads where water is to be acidified. Do not use galvanized iron or brass nozzles if possible.

Finally, if the injector is to ultimately serve more than one greenhouse, the plumbing should be of sufficient capacity to meet the demands. A work area for preparing the concentrates and storage area for the chemicals should be planned. If city water or other domestic water supply sources are used, local codes and general good practices will require a check valve or gravity break, to prevent any backflow.

6.5 Controls, Security, and Instrumentation

CTS operations can use greenhouses with fully controlled environments or in very mild climates, use no greenhouse at all (i.e. growing the trees in containers outside on a gravel or asphalt base). Between these extremes there are semicontrolled operations where trees are sheltered from rain to maintain control of irrigation and fertilizer regimes and mechanically protect seedlings (fig. 6-31). Some of these semicontrolled operations include provision for temporarily enclosing the structures and adding supplemental heat to protect plants from excessively low temperatures. Controls are usually simple—irrigation and fertilization control, protection from low temperature extremes by simple heaters and enclosures, and ventilation through roof vents using convection or, in some cases, gable-end fans. Operation of these controls may be manual or automatic.

Once a decision has been made to build a highly controlled green house, all controllable factors should be controlled for two reasons: (1) if a greenhouse is constructed, with all the associated expense and trouble, its capability should be utilized to the fullest extent economically practical, and (2) plant growth will be maximized when all factors needed for growth are optimized. The same applies even to semicontrolled houses, within the limits of the capability of the structure.

6.51 Temperature Controls

A greenhouse environmental control system not only includes the structure, but also automatic vents, fans, cooling systems, heaters, sensors, and controllers. All the machinery does not operate at once. The heaters warm the greenhouse, ventilators bring in fresh air, and the cooling pads cool incoming air, as needed. If all the equipment were on at once, it would be working at cross purposes. Consequently, the most efficient and economical way to keep the greenhouse environment at a preset optimum condition is to "stage" the temperature control equipment so that various components come on to meet the different levels of heating or cooling demand.

For example, suppose the air temperature in a greenhouse rises above optimum because of an increase in solar radiation. First a single exhaust fan is turned on. If the temperature continues to rise, the pump that wets the cooling pads is turned on. If the latter is the final stage of cooling, the temperature should begin to go down, provided the house was designed properly for the site conditions. As the temperature falls, the cooling pad water pump shuts off, then the fan.

The cooling system has passed through three "stages" from neutral (nothing running) to full cooling (stage 2) and back again, making a graduated response to a temperature change. The number of stages a greenhouse climate system can go through depends on the mechanical equipment and the sophistication of the control system linked to it. The amount, type, and size of the temperature control equipment (i.e. exhaust fans, ventilating fans, perforated tubes, heater, motorized shutters, turbulator fans, and cooling pad system) will vary from greenhouse to greenhouse, depending on how the house was engineered to meet requirements of the crop and site. The more sophisticated control systems can stage through a dozen or more steps from maximum heating to maximum cooling. Controllers operate by stages to:

1. Reduce equipment wear.
2. Save fuel and power.
3. Keep the greenhouse environment near optimum (less modulation).

6.52 Types of Controllers

Temperature control systems use one of two basic types of sensor.

Thermostatic control systems.—Greenhouse thermostats are electrical switches activated by expansion or contraction of an enclosed fluid caused by air temperature changes. Thus, a thermostat is a "go" or "no go" switch at any given temperature. Consequently, each thermostat can operate but one stage of a control system, and a number of thermostats are required to operate a staged system. If the neutral set point for the greenhouse is 70° F (21° C), the first stage cooling thermostat may be set at 72° F (22° C), and the second stage at 75° F (24° C). Some work in setting the individual thermostats is necessary to prevent the stages from "bucking," or acting at cross purposes with each other. The most commonly used greenhouse thermostat is a 120-volt, 15-ampere unit with a range of from 30° F (−1° C) to 100° F (38° C) and a 3° F differential (i.e. it can be set to an accuracy of about 1.5° F (0.8° C). These units are relatively inexpensive ($20-$25 each). A battery of these thermostats, one for each heating and cooling stage, is positioned near the center of the greenhouse where they are shielded from irrigation water and sunlight. However, their protective covering must allow free air circulation around the thermostat (fig. 6-32). The advantages of the thermostat control system are:

1. The system is 120 volts and can be wired and maintained with electrical hardware readily available in most hardware stores. Most electricians can readily understand, wire in, or service it, an advantage for greenhouses in rural areas.
2. The thermostats are cheap and easy to replace. Spares can be kept on hand.
3. The system depends on multiple, independent sensors. Each sensor and its stage of equipment is independent of the others. Mechanical failure of one sensor or system does not upset the other stages. If one stage does not work, the next stage will when the temperature reaches its s point.
4. All greenhouse machinery and controls can b the same voltage.

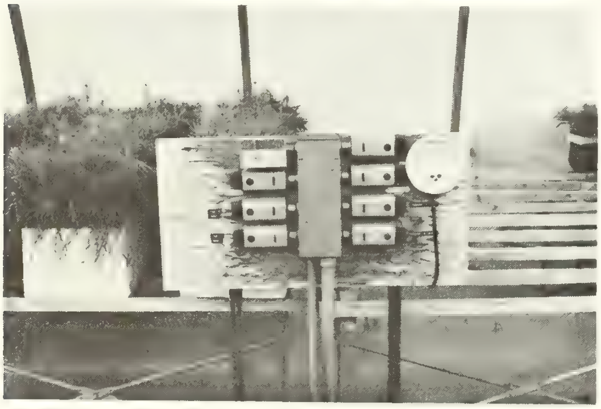


Figure 6-32.—Thermostat controls for a greenhouse, one for each stage of heating and cooling, and separate thermostats for day and night furnace settings.

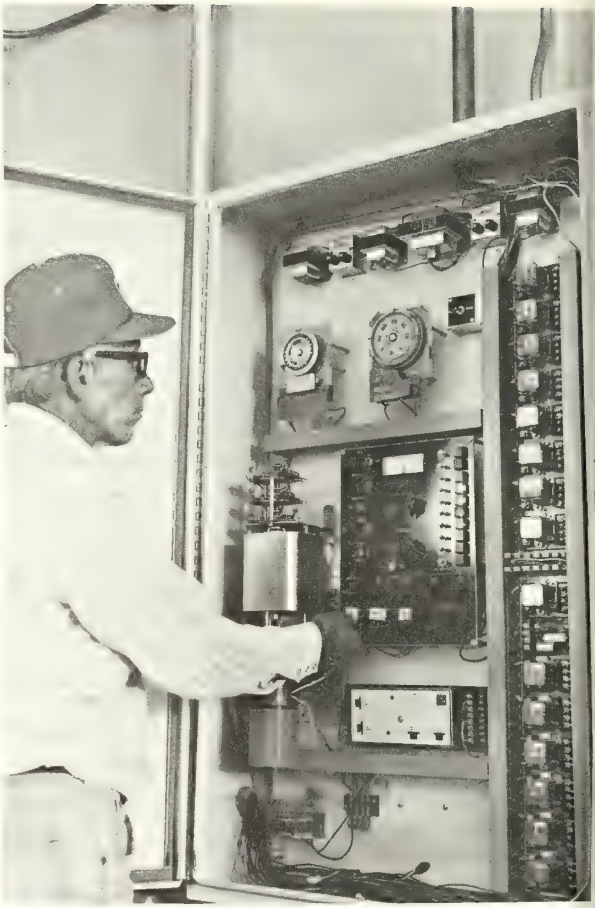


Figure 6-33.—Integrated heating and cooling contr system with thermistor sensor. (Photo courtesy Kansas Cooperative Extension Service.)

The disadvantages are:

1. Much of the modern greenhouse contr equipment is 24 volts. Wiring for 120 volts much heavier, and usually has to be in condu in a greenhouse, and is much more hazardo in wet conditions.
2. The system described cannot be purchased an assembled package, but must be design and assembled piece by piece.

Thermistor control systems.—Thermistors a semiconductors that proportionately conduct mo or less electrical current as they get warmer or colde Since a thermistor senses changes in temperatu over a range instead of at one point, only one needed for temperature sensing in a greenhouse. T control panel actuates different heating or cooli stages at different preprogrammed temperatures (fi 6-33). These systems can be purchased with few nany stages and numerous optional panels that will ctuate accessory control equipment. The systems re usually designed for 24 volts. Manufacturers will ailor the system and accessories to the needs of the leveloper and will install and service it. These ystems can be very expensive to purchase and naintain. The greenhouse developer should be sure o buy features he needs, but not more than he needs. ewer models have solid state controls which rovide added reliability. The advantages of the hermistor temperature control systems are:

1. The systems are usually 24 volts, which are inexpensive to install and safe to use.
2. The systems can be tailored to and completely packaged for a given operation. Installation and maintenance can usually be purchased from the manufacturer.
3. Only one sensor unit is needed.
4. Special features are often built in or can be purchased as accessories. Examples are: day and night temperature setback, override switches, cooling water pump, shutoff during freezing weather, modulating vent or steam valve control, phase failure disconnects, decondensate cycles, and automatic CO_2 injection.
5. The sensitivity of thermistors can be adjusted.

ome of the disadvantages are:

1. Because of the complexity and unique nature of the equipment, many areas lack parts and maintenance service. With the exception of replacement of modular parts, a specialist is required for repair.
2. If the single sensor (thermistor) fails and another is not readily available, the entire system is out of order. This would also be true of some of the panel parts such as the sequencer (critical replacement parts should be kept on hand as recommended in section 21).
3. Since these systems can be purchased to provide very automatic operation, there is a tendency to check functioning less frequently than is prudent.
4. Two voltages are required in the greenhouse electrical system.

Choice of a system depends on the developer's eeds, preferences, and available money. There are ther types of proportional thermostats available hich use bellows-operated potentiometers for roportional control of heating equipment such as eam valves, but they are not used in connection ith modern temperature control panels.

.53 Lighting Controls

Light to interrupt the dark period is usually con- olled by time clocks. In a typical setup (fig. 6-34), a 4-hour time clock turns the lights on in the evening and off at dawn. This function can also be performed by a photocell which eliminates the need to reset the clock as the natural day length changes throughout the year. However, a photocell will gradually lose sensitivity, and should be cleaned periodically as dust accumulates. A 60-division timer with a cycle time from 6 to 60 minutes in series with the 24-hour clock or photocell is set to turn on the lights 1 minute out of 30, 12 seconds every 6 minutes, or anything in between. Some tree species may require more light than others, so, the clock could also be set to give light 1 part in 15 or 1 part in 10. Details are provided in section 12.

A smaller, cheaper electrical entrance can be used effectively, especially in large installations, if the lights are not all turned on at once (section 6.23). Because they are on only a small portion of the time, they can be divided into separate banks. One bank comes on and goes off, then the next and so on. This is controlled by a programmer or sequential cam timer which is in series with the other two time clocks.

In small greenhouses, these controls may operate on 110 volts and control the lights directly, but usually the timers operate relays which operate the lights. This intermittent lighting system works well with incandescent lights, but not with fluorescent or most arc lights (section 6.2). These lights must stay on continuously and are adapted for use on a moving boom, on which the only control needed is the 24-hour time clock or photocell.

All of the electrical controls will be safer and last longer if they are kept out of the greenhouse where they are continually exposed to high humidity and may be splashed with salty acidic nutrient solution.

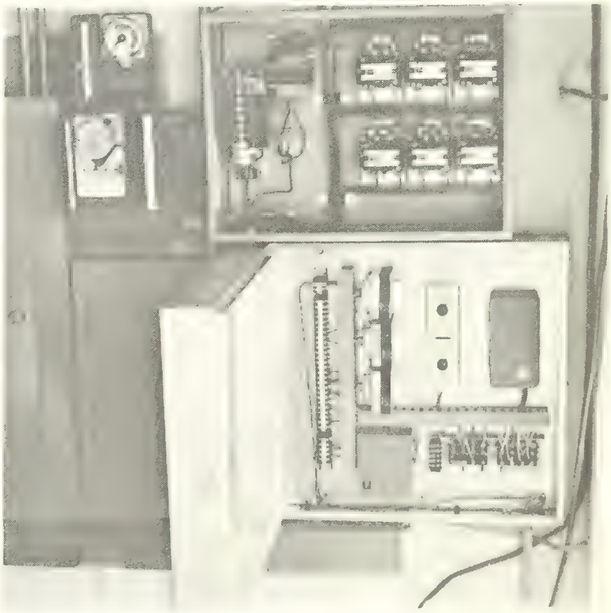


Figure 6-34.—Typical controls for greenhouse lighting.

6.54 Humidity Controls

Proper relative humidity must be maintained in the greenhouse for optimum plant growth and disease control (section 11). Generally, most CTS greenhouses do not have mechanical devices specifically for humidity control. This feature is usually designed into the ventilating, heating, and cooling system.

The basic unit of control is the humidistat, which has a humidity sensor hooked to a single pole double throw switch. Thus, it can be wired to close on rise and dehumidify, or close on fall and humidify.

Dehumidification is the most common need in humid climates. It is most often accomplished by ventilation (i.e. the humidistat turns on an exhaust fan when the humidity rises above a certain level). If ventilation alone is not effective, a combination of heating and ventilation will be, even if the outside air is saturated.

Humidification is the most common need in dry climates and during cold weather when the heat is on. The humidistat may control the injection of steam or mist into the air circulation system, but there are other sources of humidity that are useful but not as easily adjusted on demand. The seedlings transpire, and humidity can be conserved by merely reducing exhaust ventilation. Doing so may not be practical, because ventilation is primarily for temperature control. Another conservation method is to use a double layer covering on the greenhouse. When a greenhouse has a single layer cover and the weather is cold, moisture will condense on the interior wall and roof surfaces. Much of this condensation will drip on the floor, drain away, and be lost from the greenhouse atmosphere. Evaporative cooling adds appreciable humidity to the air, but this must be regarded as a beneficial side effect of temperature control. Likewise, irrigation commonly brings the humidity to 100% for hours and even days at a time. Where humidification is needed, this is beneficial, but wet foliage is an invitation to disease, and some water supplies may leave harmful salt deposits if allowed to evaporate on the foliage. For these reasons irrigation for humidification should be done with care.

6.55 Security and Reliability

The subject here is not protection of the greenhouse installation from vandalism, although that is something the developer must also consider. The main concern is security and reliability of maintenance of the growing environment for the crop (i.e. the mechanical provisions to alert the nurseryman to mechanical failure, power interruptions, and other problems (section 21).

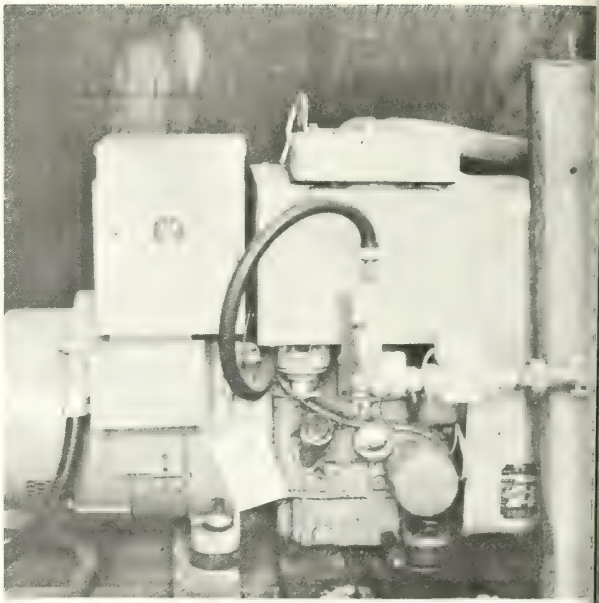


Figure 6-35.—An emergency generator big enough to r the essential heating and cooling is a good investment.

Probably the most common device is a thermost which senses an abnormal change in greenhou temperature and sets off an alarm. This can be device that automatically dials a prescribed pho number and plays a prerecorded message. Sor alarm systems can be programmed to sequential ring several phone numbers in case the first is busy does not answer. If a grower or his representati lives on the greenhouse site, a thermostat actuating bell or horn in the residence may be adequate. Mc sophisticated alarm systems can detect and indic particular mechanical failures. Some alarm syste can pinpoint the control system step that is malfu tioning, a valuable feature when a multistep system is malfunctioning. Some can automatica start backup systems. Most are independent of regular electrical power supply.

Common causes of temperature emergency electrical power failure, loss of fuel supply to f naces, or pilot light failure in the furances. Ma modern greenhouses rely on furnaces requiring el tricity for fuel ignition and heat distribution. C versely, in hot climates, electricity is needed to ventilating fans and cooling system water pum Therefore, every prudent greenhouse operator provide an alternate electricity source for em gencies. Normally these are gasoline or die powered generators large enough to keep essen equipment running (fig. 6-35). In large greenho operations, they are self-actuating. If the regu source of power is off for a certain length of ti they start up and automatically shut down a regular power is restored. Most backup po systems used by CTS operations are manual start nd shut-down types, because of the relatively small cale of the operations.

Greenhouses that rely on fossil fuels for heat rarely ave alternative heating systems to insure against oss of fuel supply. Delivery of natural gas has a ecord of high dependability. Fuel oil or propane upply should be monitored and refilled regularly. lways maintain an adequate reserve. The need for lternative heating systems when depending on solar nergy for heat is discussed in section 4.13. Reliaility of heating for a greenhouse, exclusive of fuel nd power, is increased greatly by redundancy of quipment (i.e. several heaters).

The operation of photoperiod control is important o monitor. Since it operates only at night, malunctions can be overlooked, especially if there is no esident nurseryman. Sometimes, malfunctions are irst noticed after apical growth by the trees ceases. his should not be allowed to happen. The system an be monitored with a recording voltmeter or hotometer. With either of these instruments, malunctions could be detected by checking the chart aily. Latitude for loss of the interrupted night varies mong tree species. One or two nights' disruption is sually not catastrophic. A more direct way to onitor the lighting system is to link a photocell to a me clock programmed for the same intervals as the me clock for the photoperiod control. If the hotocell did not receive light from the greenhouse ghts during the "on" period a switch would be rown activating a flashing light that would operate ntil the following morning. The nurseryman would en check operation of the system and locate the roblem. The authors know of no such system resently in operation, but it should be simple to onstruct.

In summary, the CTS greenhouse should have (1) ome sort of low and high temperature alarm system,) a backup electrical power system, and (3) some ethod of checking the lights that interrupt the dark eriod.

.56 Instrumentation

Every containerized tree seedling greenhouse peration requires certain instruments for adequate ontrol and monitoring of the operation. Some struments are basic and should be in every green- ouse; others are useful but not essential. Instruents vary from simple hand-operated models to phisticated ones which automatically record their adings in a data logging system (Kelsoe 1975, mort et al. 1977).

Hygrothermograph.—A hygrothermograph senses d records temperature and relative humidity (fig. 36). It provides the grower with a 24-hour-a-day record of these two measurements. At the end of the growing cycle, there is a documented record of temperature and humidity for the growing period. It provides an accurate check on calibration of sensing devices attached to the control system. The hygrothermograph also can be moved to various locations in the greenhouse to check for hot or cold spots, or it can also serve as a standard at one location while other spots in the greenhouse are checked with thermometers. This instrument is usually housed in some protective structure to keep irrigation water and direct sunlight off it but allowing free air flow over the sensing elements in the instrument. In some cases this shelter needs to be aspirated to assure accurate readings. The housing should be designed for quick and easy access to the instrument so that the graph paper can be replaced, the clock wound, and the pens inked easily.

Hygrothermographs cost between $200 and $400. The most common type has a vertical drum. The recording chart is fastened to the drum which is turned by a manually wound clock mechanism. Pens attached to sensing mechanisms record current temperature and relative humidity on the chart as the drum revolves. Electrically driven drums requiring line power should be avoided, because plugged in appliances in a greenhouse are inherently unsafe, and because their recording will stop if there is a power failure. The grower should plan to have at least one hygrothermograph for each greenhouse. Most hygrothermographs are built to National Weather Service specifications which help assure accuracy and long life. However, each facility should have at least one set of Weather Service approved maximum-minimum thermometers and a psychrometer for checking and recalibrating the hygrothermographs periodically.

pH Meter.—The soil reaction or pH value is a useful index of conditions associated with nutrient availability and plant growth (section 13.3). Wilde (1958) reviewed the relation of soil reaction to the growth and distribution of forest vegetation. The

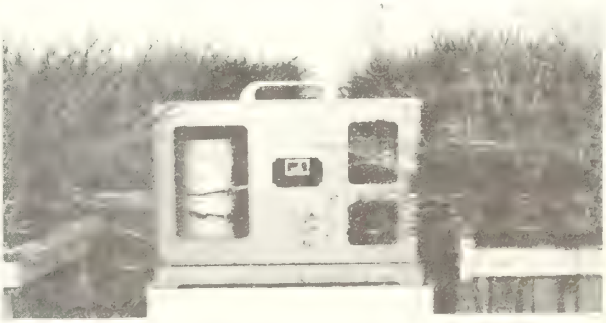


Figure 6-36.—A hygrothermograph is an essential greenhouse instrument which should be set at plant level, but may or may not be in a shelter.

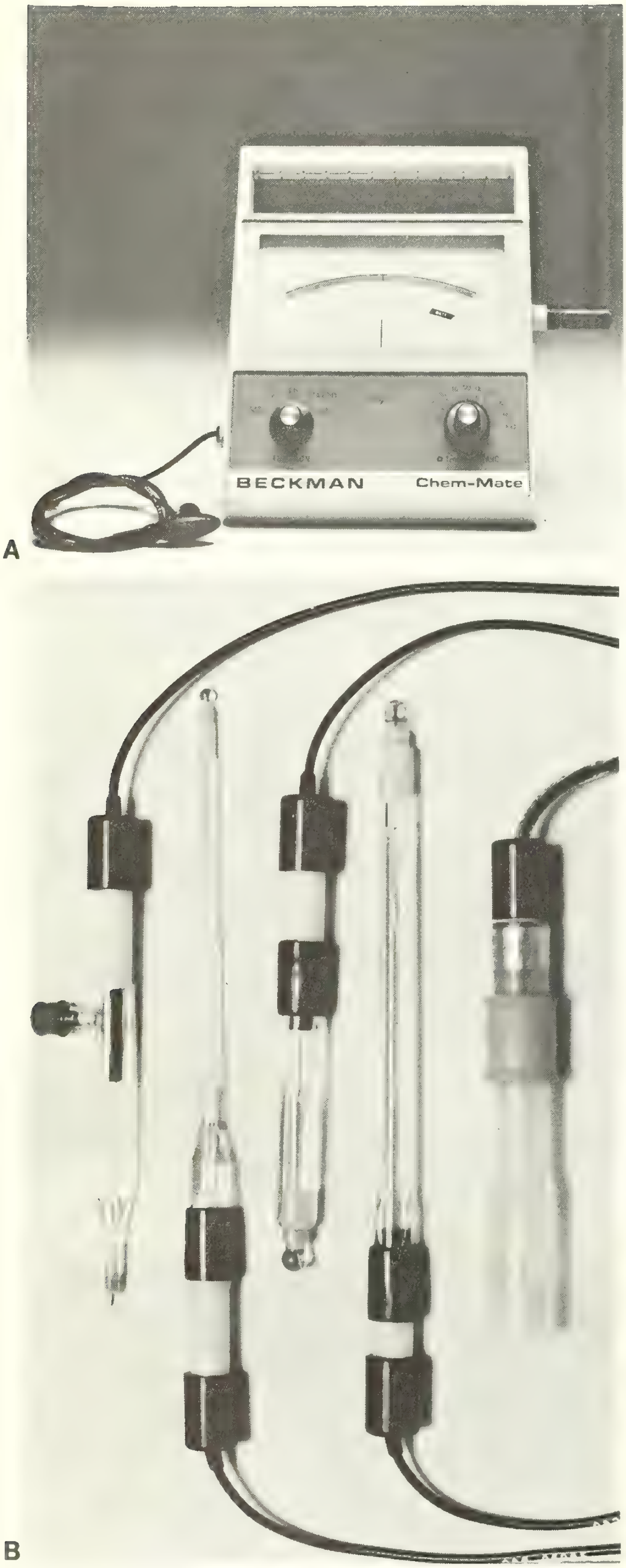


Figure 6-37.—Portable pH meter suitable for greenhouse use (A), and commonly used electrodes (B). (Photos courtesy of Beckman Instruments Co.)

importance of proper pH in the soil solution to growth of conifer tree seedlings has been demonstrated (Brix and van den Driessche 1974). The optimum pH of soil solution for container tree seedlings is discussed in section 13.3 together with methodology for monitoring the modifying CTS soil solution pH. The CTS nurseryman needs a meter that is accurate and readable to the nearest tenth (1/10) pH unit (fig. 6-37). The instrument should have a general purpose glass combination electrode and be built for rugged field (not laboratory) use. Portable battery-operated units are probably best for CTS operations. Battery-operated units should be the push-to-operate type to avoid battery exhaustion by leaving the switch on. In large operations, where many pH checks are conducted and bench space is available, a 110-volt bench unit may be best. Don't buy more instrument than is needed. Suitable pH meters cost between $100 and $250.

Conductivity meter.—Electrical conductance of solutions extracted from soils gives a quantitative estimate of the salt content (Jackson 1958). Containerized tree seedlings are heavily fertilized to promote optimum growth. If the containers are not adequately leached during irrigation, enough salts may accumulate in the growing medium to damage the trees. The electrical conductivity of the leachate from the containers indicates whether such accumulation is taking place.

Detailed instructions for procedure and interpretation of electrical conductivity readings can be found in section 13.4. Generally, a portable, battery-operated, direct-reading meter providing readings from 1/10 to 5,000 PPM is adequate (fig. 6-38). Accuracy of +2% is good enough. As with the pH meter, a battery powered unit is probably best. It should be equipped with a push-to-read switch to avoid power drain between uses. The meter will have a tuning dial and an indicating needle, or a pair of lights to indicate the balance point. A cats-eye tube is hard to read in bright light. A better type for nursery use is one with lights, usually one red and one green. A low setting turns on the red light; a high setting turns on the green. When both lights are off, the conductivity is read on the dial. Conductivity meters of this type cost $100 to $300.

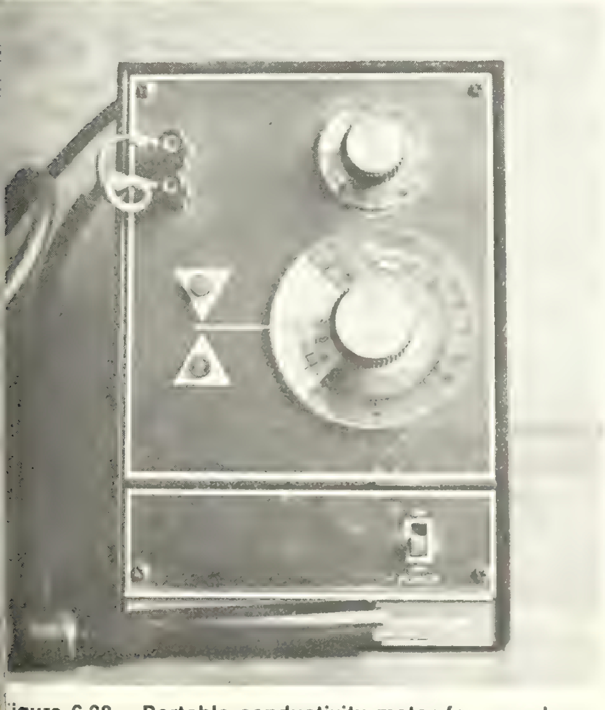
A hygrothermograph, pH meter, and conductivity meter are essential for good CTS greenhouse operation. Several other instruments are useful but not absolutely necessary.

Flowmeters and pressure gauges.—Many types of nutrient injector and spray nozzles are designed for trouble free operation for a long time. However, they corrode, wear, plug up, and become inaccurate (section 6.4). Properly located flowmeters and pressure gauges will tell the nurseryman if his irrigation and fertilization equipment is working as it should (fig. 6-39).

The proportion of nutrient stock solution to water is determined by the rate of stock solution injection and the flow rate of the water supply. With flow meters of the proper size on both the stock solution intake and the water supply, the nurseryman can divide one flow rate by the other and quickly determine if the injection ratio is correct. If it is not, the injector can be adjusted. If the inaccuracy is caused by wear on a fixed injector, the concentration of the stock solution can be changed to make it right for whatever ratio the old injector is producing. The flowmeter on the water supply is also an easy way to keep track of water consumption during crop growth.

Pressure on the water supply line may fluctuate for many reasons. Although this will not affect proper operation of many injectors, it will affect the length of time needed to complete a watering, and will affect the distribution pattern of water from the nozzles. A pressure gauge on the water supply line will indicate whether the watering time needs to be changed, and if the nozzles will work properly. It will also indicate water supply problems that need correcting.

Some nutrient injectors operate by compressed air and are sensitive to pressure changes in either the air or water supply. A normal complement of instruments for compressed air injectors includes two flowmeters (for stock solution and water supply), two pressure gauges, and two pressure regulators (for air and water).



igure 6-38.—Portable conductivity meter for greenhouse use.

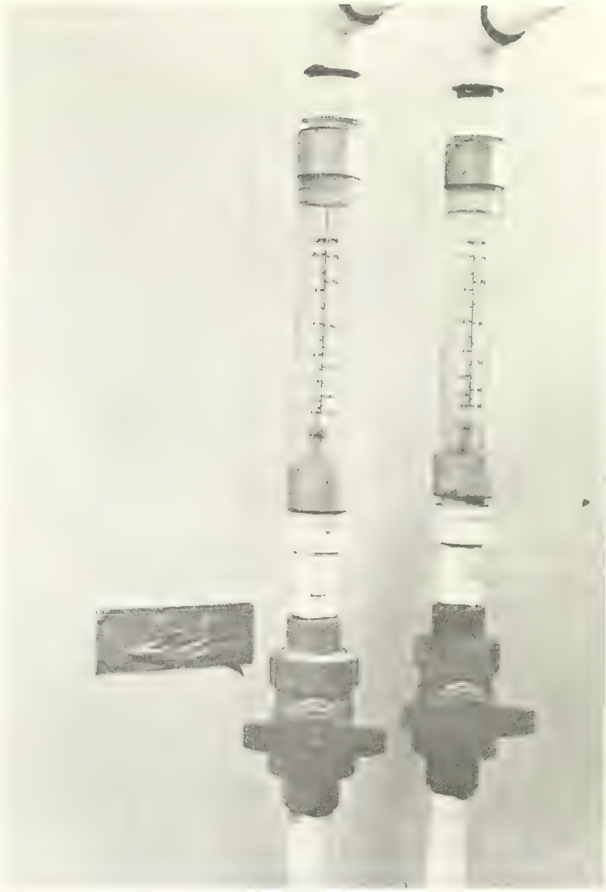


Figure 6-39.—Flowmeters used to control irrigation and fertilization. Flow rate is read from the top of the stainless steel float.

Since nutrient solution is always salty and usually acidic, all instruments downstream from the injection part should be of stainless steel, rubber, and plastic with no brass, copper, or iron parts.

Soil moisture monitoring equipment.—Maintenance of optimum soil moisture conditions in containers is important to achieve growth rates. There are several ways to monitor the amount of water in the container. The simplest is direct visual and tactile observation based on experience. It generally requires little disturbance of the seedlings. The instruments that can be used are limited. Most tensiometers have probes too large to use in small containers. Similarly, most electrical resistance blocks are too large.

Scales are used to weigh the container(s) to compare current weight with the weight of saturated containers and the weight of dry containers. With allowance for the weight of the trees, the amount of water in the container can be determined. Such scales are usually bench models capable of weighing up to 50 pounds (23 kg). Portable scales can be taken into the greenhouse. A high degree of accuracy is not necessary; ±10 gm should be more than adequate. The platform of the scale should be flat and large enough to conveniently accommodate the container used. Spillage of the medium from the container is inevitable, so, a scale with some shield to prevent this debris from lodging in the working parts is desirable.

A special device known as a moisture scale has a movable platform on which a container is placed (fig. 6-40). As the medium in the container dries, the platform rises. At a preset point, an electrical contact is made which turns on water valves or sounds a warning alarm. Again, as the trees grow, this added weight must be compensated for when setting the scale.

Bimetal probes to measure moisture are about the size of a pencil (fig. 6-41). The tip of the probe has two dissimilar metals that, when introduced into the container medium, produce a weak battery. The battery generates a current. A galvanometer needle is deflected proportional to the resistance of the metal plus pot mix. The reading can be calibrated to indicate roughly the amount of water in the growing medium. These probes are relatively inexpensive ($10-$15 each), and rugged.

A pressure bomb measures moisture tension in the plant directly (fig. 6-42) (Scholander 1965). When a leaf or small stem is cut from a plant, internal moisture tension draws the sap in away from the cut surface. The sample is placed in the bomb and nitrogen pressure gradually applied to the leaf or stem, while the cut surface is watched. As soon as liquid or bubbles appear at the cut surface, the pressure is read. This pressure corresponds to the moisture tension in the stem or leaf. When readings are taken in the very early morning, this will also be a good measure of soil moisture tension. There are situations where proper interpretation of pressure bomb readings is not as simple as it might seem. A working knowledge of plant water relations is highly desirable.

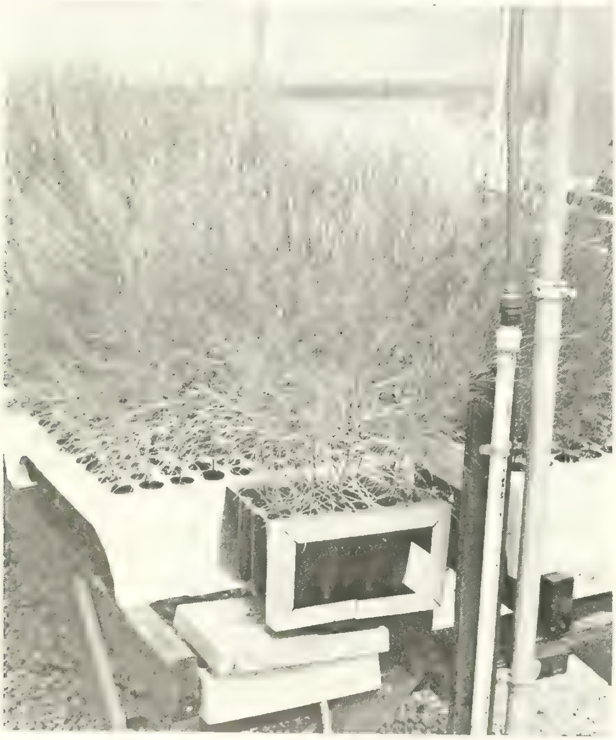


Figure 6-40.—Typical use of moisture scale in the greenhouse.

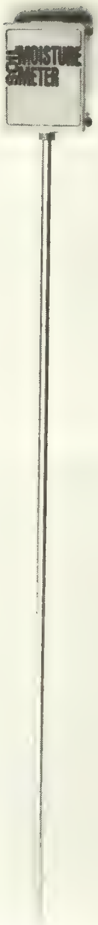
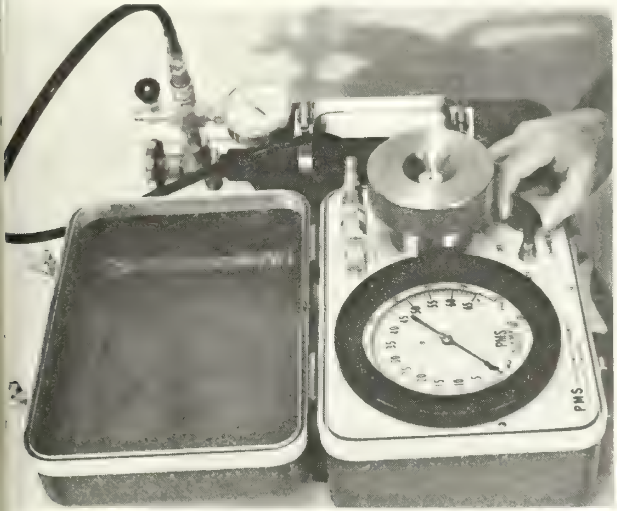


Figure 6-41.—Bimetal moisture probe is simple, small enough to use in even small containers, and accurate enough for spot checking.

Pressure bomb measurements require destruction of part of the plant. Hence, the seedlings must have enough foliage to permit a sampling. Several large nurseries rely on container weight when trees are small, then switch over to the pressure bomb when the trees reach a certain size. This appears to be an excellent method but is somewhat time consuming. However, measuring internal water tension of a tree is the best measure of moisture stress. With some testing the optimum tension ranges for tree growth can be found (McDonald and Running 1979). In general, acceptable tension ranges are from 0 to -3 bars. Pressure bombs cost about $1,000.

Each method for determining moisture status and watering needs has its own advantages and disadvantages, and none of them are applicable in all situations. The authors recommend that the nursery be equipped to use at least several of the methods. The moisture scale can be used throughout the growing cycle, but the meaning of its reading changes with the size and condition of the seedling. It takes careful calibration to use it correctly. The bimetallic probe is cheap, quick, and easy to use, and very portable, but likely to be the least accurate of the methods. Its principal use should be for spot checking. The pressure bomb is an expensive instrument but gives a direct reading of plant moisture stress. After seedlings are large enough to withstand destructive sampling, it can be used as a check on the other methods. Even with all of these instruments nothing can completely replace visual and tactile inspection of moisture in the growing medium.

A recording ammeter records the electrical demand fluctuations for a greenhouse. By interpreting these records, the nurserymen will know if the greenhouse control and lighting system is functioning properly. The alternative is visual observation or use of photocells to check lighting systems. Recording ammeters can be useful for periodic checks of greenhouse function.



igure 6-42.—Pressure bomb determines plant moisture stress directly.

Carbon dioxide analyzers are used to periodically check greenhouse CO_2 concentrations to recalibrate CO_2 equipment. The device consists of a manual air pump which forces air through an indicator cartridge or container of liquid. The cartridge or liquid is discolored to a degree proportional to the CO_2 concentration of the air. The cartridge is used once. The price of a manual CO testing device is approximately $75-$100. For small greenhouse operations samples of air from the greenhouse can be sent to laboratories having infrared gas analyzers.

Of the less necessary instruments, the authors consider those for nutrient injection monitoring and soil moisture measurement most important. Recording ammeters and CO_2 analyzers are rarely needed. It may be possible to rent or borrow an ammeter, and have greenhouse air samples gas analyzed by someone else.

6.6 Greenhouse Safety

Greenhouses have a number of inherent safety hazards which can be minimized by proper design and construction and by safe work habits. Greenhouse interiors are commonly wet, which makes floors slippery from spilled growing medium and the growth of algae. Floors should be built to minimize slipperyness and cleaned as needed when they become slippery. Because dampness makes machinery rust, keep as much machinery as possible out of the greenhouse.

Probably the greatest hazard created by wetness is the danger of electrical shock. All wiring should be in waterproof conduit. All outlets should be grounded and equipped with ground fault interrupters. Never use ungrounded tools or appliances of any kind in a greenhouse, unless they are double insulated. When repairing or adjusting electrical equipment, shut off the power first. If this is not feasible, at least wear rubber gloves and boots; use a wooden ladder instead of an aluminum one.

Greenhouse fans may start automatically without warning. For this reason the blades should be shielded so that no one can put their fingers in them.

Some greenhouses have floor-mounted heaters, which should have their flues shielded so that they cannot be touched inadvertently.

SECTION 7.—AUXILIARY EQUIPMENT AND BUILDINGS

7.1 Headhouse and Storage Buildings

7.2 Mixing and Loading Equipment

7.3 Seeding Equipment

7.4 Conveyors, Live Rollers, and Benches

7.5 Rolling Stock and Stacking and Storage Systems

7.51 Rolling Stock

7.52 Stacking and Storage Systems

7.6 Culling, Packing, and Shipping

7.7 Office Space and Accessory Structures

SECTION 7.—AUXILIARY EQUIPMENT AND BUILDINGS

7.1 Headhouse and Storage Buildings

A building referred to as a "headhouse" is often located near the greenhouse. It is used for activities such as filling containers, seeding, packaging for shipment, and storage of materials and supplies. Headhouses are usually placed on the north side of greenhouses to avoid shading them. A connection between the headhouse and the greenhouse makes operations much more convenient, but can complicate construction.

The size and type of headhouse and other buildings depend on the activities and storage requirements of a particular operation. Exact headhouse and storag requirements are difficult to establish. Duncan (1975 suggests an area equivalent to one-fourth to one third of the greenhouse space be allowed in tomat operations, but this seems high for CTS operations Storage space for materials and supplies can be in th headhouse or separate storage buildings. Storag areas are typically unheated. Headhouse work areas storage areas, and office space often are concentrate in one structure. Work area space requirements ca be determined by allowing room for functions involving shipping, receiving, potting, seeding, an maintenance. Several floor plans can be developed and flow diagrams made for each phase of work. Th plan that accommodates all phases of work best ca then be selected (fig. 7-1).

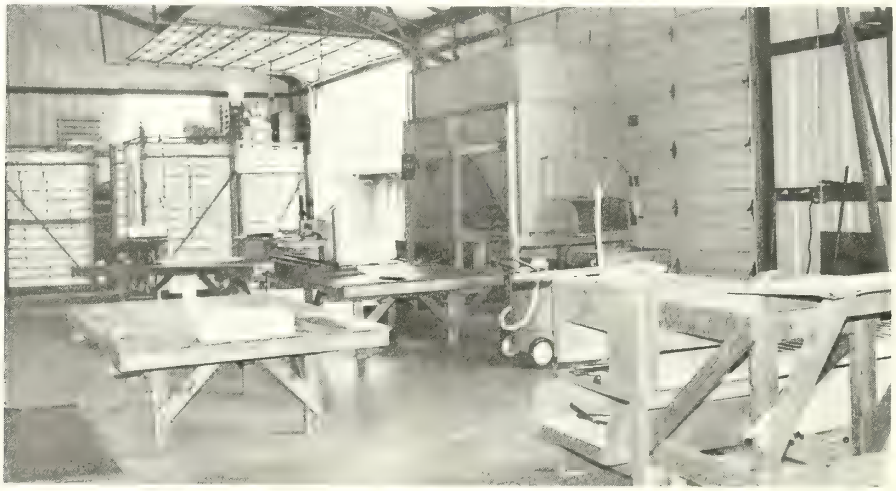


Figure 7-1.—A well laid out headhouse.

7.2 Mixing and Loading Equipment

The growing medium used in CTS culture is most ften half vermiculite and half peat moss. Sometimes hese constituents vary in favor of ground bark, erlite, or some other material. Mixing can be done t the nursery or commercially mixed potting nedium can be bought premixed. The components, dvantages, and disadvantages of mixing growing nedia on-site, and methods are discussed in section .3. A growing number of Pacific Northwest CTS perations are purchasing growing medium that is ommercially mixed. This alternative should be careully evaluated before any mixing equipment is purhased.

Growing medium mixing operations vary from imple to complex. Even some of the largest CTS urseries mix the components by hand on the floor or n a large stock watering tank. The key is thorough nixing. The mixed material is usually shoveled onto conveyor or auger that moves it to a hopper or bin hat supplies a potting table or device. Operators vho mix their media this way contend that they get dequate mixing and that it is such a brief job that it s cheaper to buy the labor than to invest in mixing nachines.

The two major components of most CTS growing nedia, vermiculite and peat, are usually bought in ags or bales. The peat is usually in plastic bags, the ermiculite in paper ones. Both are best stored inside r under plastic or canvas tarpaulins outside. Some eat is well decomposed and has a granular consisency; some is fibrous, clumpy, and still resembles he original foliar structure of the peat moss. These lumps of peat may not readily break apart during he mixing process. Some nurserymen put the peat hrough hammer mills or compost shredders to make uniform. Patterson (1969) used a shredder as his nixing device by putting all of the components of his ot mix into the shredder together with fertilizers. he mixing was then finished with shovels.

There are many mechanical ways of mixing the rowing medium. It can be done on a small scale with portable cement mixer, small endloader, manure preader, or a specially designed and manufactured rowing medium mixer. In large scale CTS operaions, large custom mixing machines can be used. ften, large old cement mixers are used that were riginally mounted on trucks. When such units perate efficiently and can be purchased at a reasonble price, these may be a viable alternative. Renting nixing equipment is another alternative. At a U.S. orest Service nursery in Idaho, this operation is ompleted in a couple of hours by having a comnercial cement mixing truck do the mixing on site. A arge amount of material (15-20 yd^3 or 12-15m^3) is nixed in a short time. However, some nurseries have found that the tumbling action creates balls of mix which must be run through a shredder or broken up by hand before the containers can be filled.

Some components of a CTS pot mix are sometimes hydrophobic. If the mixture is put into containers dry, it is frequently difficult to moisten it by sprinkling. Therefore, in contrast to many soil-based or sand-based potting operations, the growing medium must be moistened during the mixing process. This means the moistening must take place before containers are filled and that the containers must be seeded and irrigated before the pot mix in them dries out. Consequently, it is best to mix just before the filling and sowing operation. This, together with capital and labor availability and scale of operation, determines the equipment for the mixing operation. The developer should gain some experience in CTS operations before investing in expensive mixing equipment.

Loading equipment.—In small to medium operations, containers can be loaded with growing medium manually with very simple equipment more efficiently than would be expected. In large operations, mechanization becomes feasible to save labor and time.

The steps of the process are: filling the containers and compacting or compressing the medium in the containers. Seeding equipment is discussed in section 7.3. Containers can be filled by hand, but a raised hopper is commonly used. Such hoppers have manually operated gates on the side that open onto a work surface where the empty container is (fig. 7-2). Gravity causes the medium to flow out of the gate, then it is manually spread across the top of the container block. The cavities are carefully filled to the top to avoid air pockets. To increase work efficiency, the containers are often moved to and from the work station with live rollers. The workers then spend maximum time filling containers and minimum time moving to and from the work station.

Growing medium vibrators and shakers.—In many instances, CTS nurseries have devices to shake containers to settle the medium and avoid air pockets. Many are homemade. One version has a framework with eccentric camshafts underneath which, when turned by an electrical motor, alternately raise and drop the container block.

Several mechanical specialty companies have developed equipment that fills CTS containers semiautomatically (fig. 7-3). These usually consist of a hopper to hold the mix and an integral conveyor to move the mix to where it is sprinkled over the top of the container block which moves by on another conveyor. Most vibrators and shakers are well made and adaptable to a variety of container types and sizes, but some are very expensive.

Compression of the growing medium.—Often, the medium in each filled cavity is compressed from the top of the cavity to some uniform depth below the lip of the cavity. This is done for several reasons:

1. To eliminate air pockets in the container.
2. To bring the mix to a uniform density throughout the container.
3. To avoid later settling in the container.
4. To shape the surface so seeds settle in the center of the cavity.

Not all CTS nurserymen compress the mix in this fashion, but most do. This is important to grow uniform high quality seedlings. There is some evidence that compression of the growing medium enables seedlings to tolerate drought better (Mitchell et al. 1972, and Hocking and Mitchell 1973). The relation between growing medium components and aeration is discussed in section 9.33. Too high a density can slow or limit root development in some conifers (Hocking and Mitchell 1975).

Mix compactors consist of small cylindrical or rectangular plugs conforming to the mouth of the cavity with a length equal to the depth of the depression desired (fig. 7-4). The end of the plug is usually dish shaped. This leaves a depression deeper at the center than the edges, so that seeds roll to the center of the cavity. These plugs are distributed over the face of the plate of metal or wood, or a drum in the case of rotary compactors, so that their positions conform to the spacing of the mouths of cavities. When the plates are pressed onto the top of the container block, the plugs compress and shape the medium in each cavity. Compactors for different container types are commercially available. They may be constructed of wood, metal, or plastic. Many CTS nurseries use homemade compactors. A variety of methods are employed to press the compactors into the cavities. Some do it by hand, others use long armed levers, and some use presses similar to a drill press.

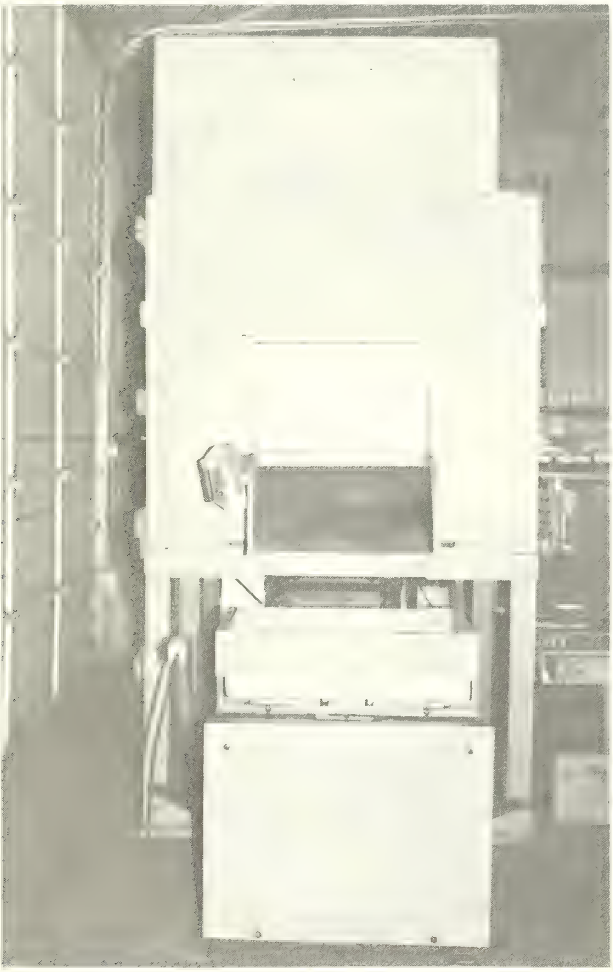


Figure 7-2.—Hopper used to dispense pot mix into containers.

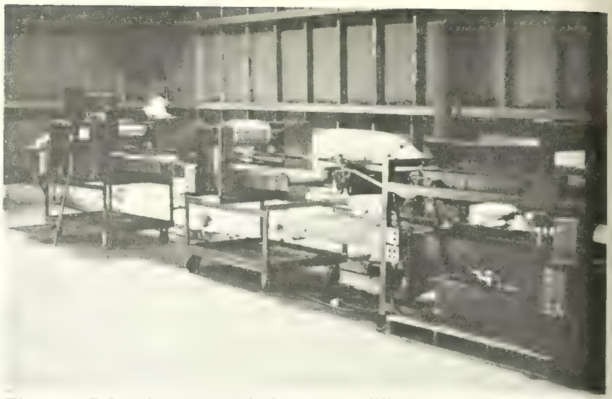


Figure 7-3.—Integrated hopper, filler, and tamper for containers.

After compression of the medium, the containers are seeded. The seed is covered with a thin layer of sand, grit, barkdust, perlite, or some other material (section 16.3). Perlite or poultry grit are most commonly used. It is spread evenly over the top of the container block in the depth desired (section 16.33). This is often done by hand. Some mechanical sowing devices incorporate spreaders that sift a layer of seed covering material onto the container block as a conveyor carries it by. Many homemade devices are used.

7.3 Seeding Equipment

CTS operations require clean, high quality tree seed. Clean seed simplifies sowing and increases speed and accuracy, and the sowing devices require less cleaning. Mechanical seeders then select fewer bits of trash to sow instead of actual seeds. High quality seed permits sowing fewer seeds per cavity, which reduces sowing and thinning costs.

Hand seeding is the simplest form of sowing. Each seed is placed in a cavity by hand. This procedure is too costly and inefficient except where small numbers of cavities are being sown for test purposes or seeds of difficult to germinate species are placed in containers after the radicle has emerged.

The most rudimentary seeding machines are box seeders made of wood, metal, or plastic. The best are made of clear plastic. The box or tray is constructed so two of the outside edges conform with the outside dimensions of the container block (making up a number of cavities) (fig. 7-5). The box has two levels separated by a space. Each level has holes drilled through it directly above the cavities in a container block. The holes in the upper level are of a size that will contain seeds (1-4 usually) of a given species. The holes in the second level are larger and allow the seeds from above to freely drop through. Between the two sheets of material is another sheet, not fastened to the sowing frame, but free to slide back and forth between the other two like a drawer-pull. This middle, movable sheet has holes identical to those in the lower level. When the middle "drawer" is shoved all the way in between the upper and lower levels, the perforations in it do not align with those in the upper or lower sheet; when it is withdrawn slightly, they do.

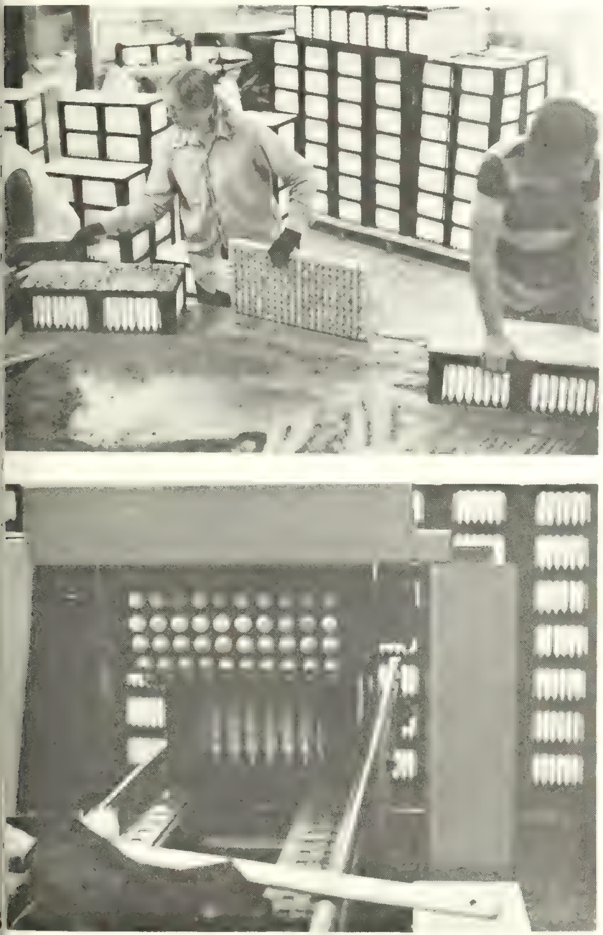


Figure 7-4.—Compactors for compressing and shaping the surface of the growing medium: (A) Flat compactor used by hand, and (B) rotary compactor as part of an automated filling line.

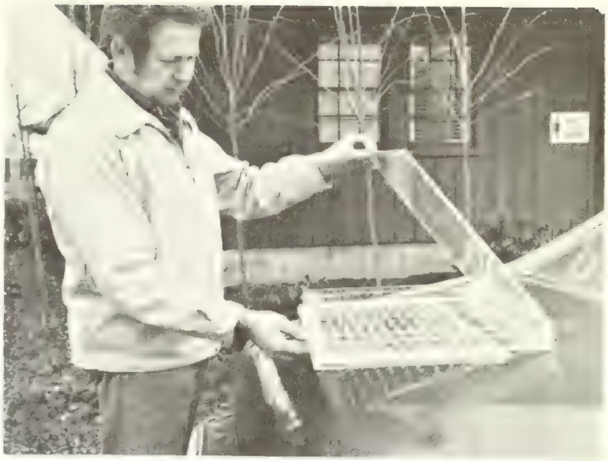


Figure 7-5.—Box seeder.

To sow the seed, the box is placed on the container block with the two flanged edges aligning the seed holes above the cavities. With the middle, movable, sheet shoved all the way in between the upper and lower layers, seed is brushed over the top surface. Depending on the size of the top layer's perforations, one, two, or more seeds fall into each hole. They are retained by the middle (movable) sheet. When all holes are filled with seed, the excess seed is removed. The middle sheet is then withdrawn until its perforations line up with those in the upper and lower layers, and the seeds fall through into the cavities. Dirty seed can complicate this method, and low quality seed can require the operation to be repeated for each container. If this simple seeding device is fully utilized by well trained and practiced personnel, astonishing seeding rates can be achieved.

Another simple device for seeding containers is a vacuum plate (fig. 7-6). This consists of a flat surface with small holes drilled in it. The distribution of holes over the surface of the plate corresponds to the centers of the cavities in the container blocks to be used. The size of the holes depends on the seed size. A vacuum is applied to the reverse side of the plate to suck air through the orifices. The plate is then pressed lightly down into a flat pan containing a layer of seed. With some care and patience, the vacuum will hold the desired number of seeds at each orifice. The plate is then aligned over the container block, usually in some prepared framework, and the vacuum is shut off. The seeds then fall into the container cavities. There are a number of variations designed to streamline the process, but again, clean, high quality seed is needed. Vacuum plate seeders are usually relatively inexpensive.

The tray seeding system and the vacuum seeder have several common characteristics. They require low initial capital investment and are surprisingly productive when efficiently used. Neither can be used without adjustment for different sizes of seeds or different containers. To allow sowing in containers with different cavity spacing or to seed different sized seeds, different trays or vacuum heads are necessary. No production figures for these seeders are given here. Reports from users vary widely, probably reflecting variable efficiency of overall sowing setups, labor, seed quality, and supervision. However, the potential production is 300,000 to 500,000 cavities per day. This means that these simple devices are probably practical for small to medium sized CTS operations (up to 10 million trees per year). The developer should, therefore, proceed cautiously when considering purchase of large complex sowing devices.

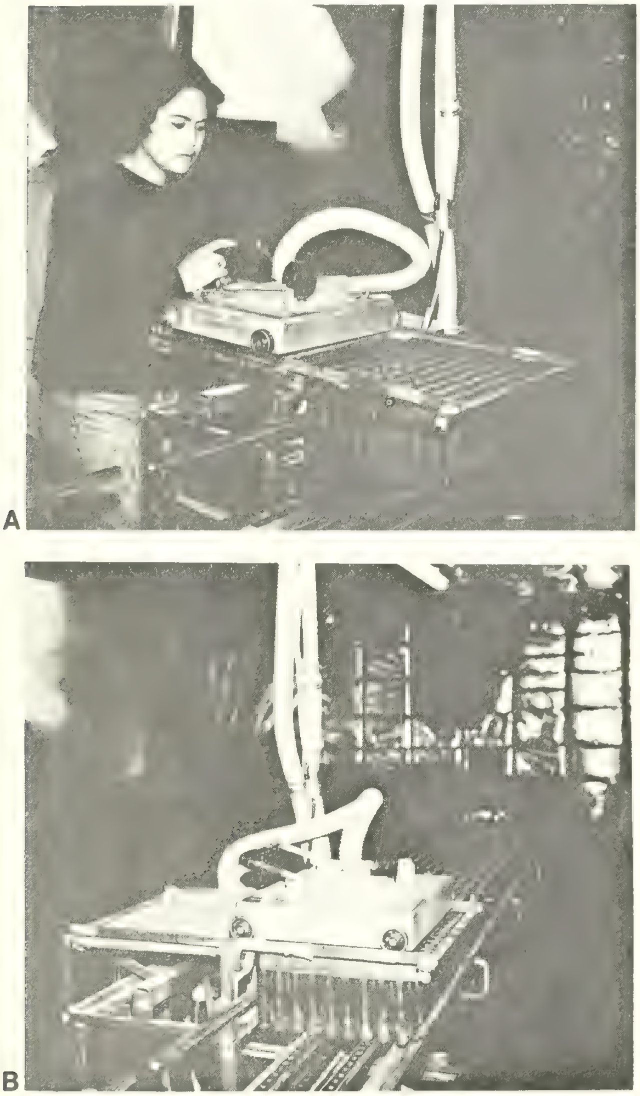


Figure 7-6.—Vacuum plate seeder picks up seed from a tray (A), and is rolled from the seed tray to the containers (B) where release of vacuum deposits the correct number of seed in each cavity.

The next level of seeding devices are labor efficient, but are more expensive and mechanically complex. These machines rely on various principles and are evolving rapidly. USDA Forest Service Missoula Equipment Development Center is preparing a catalog, to be published in 1979, listing manufacturers and describing these machines. Some are made in Canada or Europe. Some are very accurate and efficient. In large CTS operations, such high volume equipment may be essential. Instead of discussing the various types of sowing devices, the following recommendations are made:

1. Be sure the cost per unit seeded using the machine is less than the cost of using the simpler seeding devices.
2. Be sure the machine will sow seed in the containers being used and be flexible enough for others which may be used in the future.
3. Be sure to canvass present owners to see if the are satisfied with the machine.

7.4 Conveyors, Live Rollers, and Benches

Conveyors and live rollers are often used t mechanize and speed container movement i container filling and sowing processes. Except fo highly customized and sophisticated systems, suc items are relatively inexpensive and can effectivel expedite flow process. Often, they can be used i other operations at a CTS nursery, such as unloadir a greenhouse, multiplying their usefulness. A mentioned in section 4.3, a number of process flo diagrams should be analyzed during facili planning. Flow system hardware should be consi ered at the time. The alternative is assembly of the articles, piecemeal, as the process evolves ar changes.

Emphasis should be placed on minimizing wast time and motion. Key machines and workers shou be supplied with a constant flow of raw material Elevator conveyors used to fill hoppers, live rollers move containers to the filling station, and conveyo to carry filled containers to those doing the seedi will reduce the labor required and make the work more smoothly. Some CTS nurseries use conveyc to move containers in and out of the greenhous Large nurseries often evolve sophisticated flc systems using such equipment.

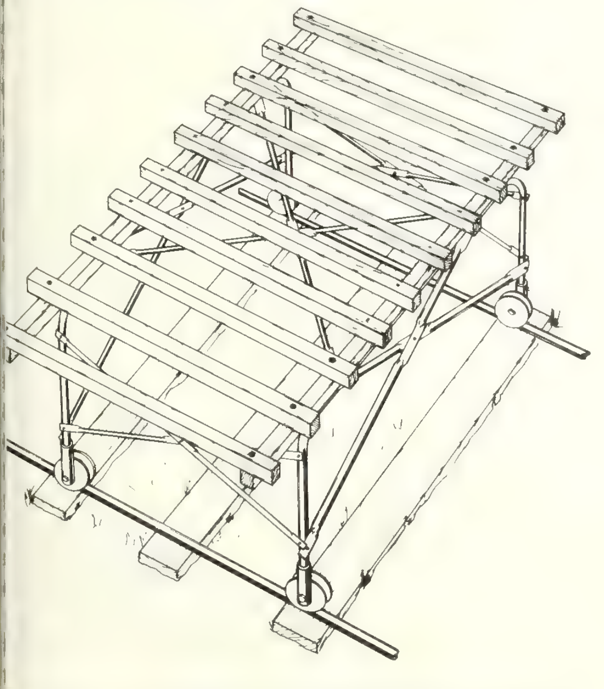
In most CTS greenhouses the containers are off t floor on some type of bench or table. These ben systems are used because:

1. They place the crop at a comfortable working height for thinning, inspection, and other work.
2. They may be modular and part of a container handling system.
3. They raise the crop above pests that may inhabit the floor of the greenhouse.
4. They allow free air circulation under and around the containers, which allows root pruning and lessens disease problems.
5. They elevate the crop above water that may be standing on the floor of the house.

Height and construction of CTS benches varies onsiderably. Most are homemade, consisting of ooden or concrete block legs and wooden frames ith wire mesh stretched over them to allow airflow the bottom of the containers. Others are quite aborate. They may be made of metal and designed allow the best use of available greenhouse space ith a minimum of room devoted to aisles. Figure 7-7 a diagram of a cartbench system developed by the orest Service that is a good example of a more phisticated design (Hiatt 1976). In general, the type bench system used should:

1. Be sized to fit the type of containers used (section 5.3).
2. Be compatible with the greenhouse door widths and dimensions of the house.
3. Be adapted to the materials handling system to be used.
4. Allow free air circulation below the containers.

Beyond these general guides, the design of the ench system should meet the needs and the resources of the greenhouse developer. Commercially built benches range from simple to complicated designs with a parallel range in prices.



igure 7-7.—A "cartbench" and track system (Hiatt 1976).

7.5 Rolling Stock and Stacking and Storage Systems

7.51 Rolling Stock

Every CTS nursery has a system to move peat, vermiculite, and containers from storage areas to work areas, and to move containers in and out of the greenhouse, etc. Some operations may use the same method of transport throughout the operation. Forklift trucks or tractors with multipurpose trailers are common. Conveyors are sometimes used for part of the work. Most often, a combination of methods is used. Probably the most efficient approach is to decide on the system to be used early in the development process. The fullest use of the selected item (such as a forklift truck) can then be incorporated in facility design and the need for other equipment minimized. The advantages and disadvantages of electric carts, tractor-trailer combinations, forklift trucks, etc., can all be itemized and compared. Remember that operation of internal combustion engines in closed spaces where people are working is dangerous and may violate safety regulations.

7.52 Stacking and Storage Systems

There are numerous methods for stacking and storing supplies. Materials handling firms will provide much advice free. In headhouse/storage building construction, it is cheaper to build structures with high ceilings. To take advantage of this, use stacking systems that will allow efficient use of such rooms safely.

7.6 Culling, Packing, and Shipping

Not every container cavity yields a usable seedling, and the process of eliminating the failures is called "culling" or "dudding." Culling can be done either at the nursery or at the planting site. To cull at the nursery, the individual containers must be separable one from another, or the tree and rootball must be extracted from the container. Different types of containers vary in their adaptability to culling at the nursery. For instance, single cells are highly adaptable; styroblocks and book planters are also adaptable, but it would be very difficult to handle paperpots this way (section 9). Therefore, which container system is selected will have an important bearing on whether it is desirable or even possible to cull at the nursery and how the seedlings are packed for shipment.

The advantages of culling at the nursery are:

1. The duds are not shipped. This reduces the bulk and weight of the shipment, and the cost.
2. Work is more efficient. Rootball extraction can be mechanized, a grading belt can be used for sorting, and the whole process can be done in assembly line fashion.
3. The container or its supporting rack remains at the nursery, which greatly reduces the wear and breakage on these components and increases their reuseability.

The disadvantages are:

1. It is one more operation to perform.
2. Some container systems are not adapted to culling at the nursery.

The alternative to culling at the nursery is to let the tree planter do it at the planting site. This simplifies the job at the nursery at the expense of making more work for the planter and slowing him down. It is justified if there is an acceptably small percentage of culls, or the nursery gives the customer a price break on the seedlings.

There are two basic methods of packing. If the containers are shipped as is, there is a minimum of handling and processing at the nursery. At their destination the container seedlings may be stored for days, even weeks if necessary, with very minimum facilities. On the other hand, the truck or trailer in which they are shipped needs to be equipped with special racks which allow room for the seedling crowns and prevent them from being crushed.

The alternative is to box the seedlings. The containers may be boxed or the seedlings with their rootball may be removed from the container, culled, packaged in plastic bags, and then boxed. The latter procedure has several advantages:

1. Boxed seedlings, culled and removed from their containers, are much more compact.
2. No special racks are required. The boxes o seedlings can be handled by the same equipment used for any other boxed goods.

However, there are disadvantages:

1. Packaging is one more operation that take time and costs money at the nursery.
2. Waterproof boxes are expensive, so, man nurseries make them returnable. Then the become another item that must be cleaned reconditioned, and stored.
3. When packed tightly together in dark boxes tree seedlings are more perishable than if lef open to the light at their original spacing in th original container. They will heat internally i allowed to become warm and may need refrigeration if stored for any length of time.

7.7 Office Space and Accessory Structures

Office space may seem to be a minor consideratio when beginning a CTS operation, but it become very important once business begins. Accordingly office space should be planned at the outset, not ju patched on later. Office space often is incorporate in a headhouse/storage building, making the structure multipurpose. Restrooms, dressing areas, an lunchrooms for workers are often included. Offic space at a large CTS nursery should be organize into three categories: (1) clerical, (2) managerial, an (3) technical. Clerical and managerial space shoul be relatively high quality. Technical areas can be le so because of the type of work done there. Instruments, such as pH meters and conductivity bridge can be housed in the technical area. Offices should b designed to expand as the operation grows. Th planner must also consider accessory structures suc as equipment storage sheds, chemical stora buildings, pumphouses, and visitor informatio facilities. These structures can be sized to anticipate needs.

SECTION 8.—SHADEHOUSES

8.1 Function of Shadehouses

8.2 Bedhouses—What Are They?

8.3 Shadehouse Coverings

8.4 Using Shadehouses

8.5 Shadehouse Irrigation Systems

8.6 Shadehouse Floors

8.7 Size and Number of Shadehouses

SECTION 8.—SHADEHOUSES

Shadehouses are shelters where seedlings can be rown full-term (in mild climates), can finish rowing, can be kept over winter, lapse into ormancy, or simply be kept before shipping while he greenhouse is loaded with a new crop (fig. 8-1).

8.1 Functions of Shadehouses

Besides providing space for storing trees, shade-ouses can:

1. Reduce the temperature below what it would be in direct sunlight by shading. The degree of shade is usually about 30% to 50% (enough light to allow the trees to remain in a normal condition, but still be cooled). The cooling effect tends to hasten dormancy in the fall and keep seedlings dormant in the spring.
2. Reduce shock when the trees are removed from the greenhouse in a succulent condition.
3. Reduce foliage scorching caused by dessication of foliage in cold weather when roots are cold or frozen.
4. Reduce evapotranspiration rates in summer. This lessens the need for irrigation.
5. Protect the trees from high winds, hail, heavy rains, and in some cases, animals. Shadehouses designed to counter these impacts must be stronger than the usual structures.

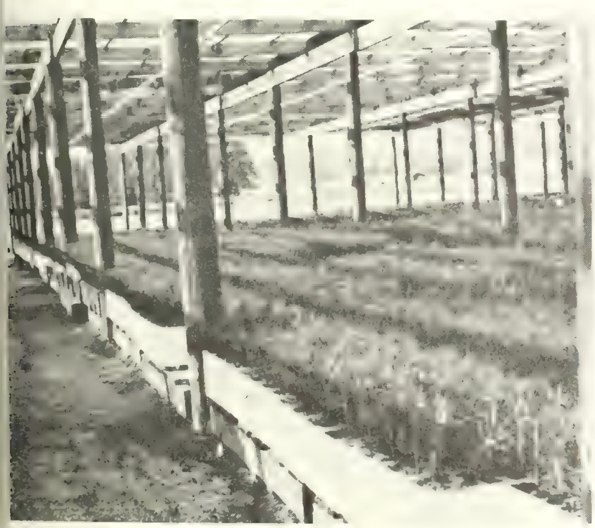


Figure 8-1.—A typical well organized shadehouse.

The need for a shadehouse at a CTS operation depends upon the weather and the production scheme. In some conditions, a shadehouse may be nearly mandatory, but in others, it is only a convenience.

8.2 Bedhouses—What Are They?

Traditionally the term "bedhouse" has referred to a minimal structure used to protect plants in the winter in ornamental nurseries. They consist of bow-arch frames covered with plastic sheeting.

Recently, the term "bedhouse" has been used to denote facilities used at tree nurseries to speed seedling growth or allow early sowing to produce tree seedlings more rapidly than with conventional bare-root nursery methods. In this context, bedhouses represent a degree of cultural control intermediate between outdoor bare-root beds and greenhouse container facilities, where bare-root stock is raised under a greenhouse with a degree of climate control. This procedure has been evaluated several times and is currently being tested by the U.S. Forest Service at Coeur d' Alene, Idaho (Tinus 1978a). Indications are that bedhouses can extend growing seasons to a modest degree, possibly provide larger planting stock in a shorter time, and protect young seedlings from severe weather. However, costs must be carefully evaluated on a case by case basis to see if bedhouse operation is economically practical, given the growth and protection benefits accrued. Also, since they are normally engineered with a minimum of automatic equipment, they must be conscientiously monitored and operated to avoid temperature extremes detrimental to the trees.

8.3 Shadehouse Coverings

Shadehouses are normally covered with either lath or woven plastic shade cloth. The lath can be nailed individually on the lathhouse structure, but more commonly, wire-bound snowfence is used. Lath is usually spaced to provide about 50% shade. Sides of a lathhouse are often covered with lath, except for an entrance. South and west sides are nearly always enclosed for shading. Shadehouses used for rearing seedlings through a complete growing cycle must be bird-tight.[1]

Shade cloth can be purchased in various percentages of shade (density of weave) and in various lengths and widths tailored to customer's needs. For CTS shadehouses, 50% shade weave is normally used, but 30% weave is becoming more popular in the Pacific Northwest due to the mild climate there.[1] The material is used on conventional post and beam frames, on large bow-arch frames, or on wire frames stretched over upright border posts. It must be stretched tight and tied down to prevent whipping and tearing in high winds. It also is lighter than lath, so, the supporting structure can be lighter. The life of shade cloth is several years, if it is well cared for. Shade cloth should be furled or taken down in winter, because it will collect snow, rip, and collapse under weight. It is also more prone to wind damage when the weather is cold.

Shadehouses made of lath can also be damaged by heavy snowfall. In areas with heavy snowfalls (12 inches (30 cm) of wet snow) lath on the roof should be in rolls so that it can be rolled up in winter. If the lath is nailed to frames, these should be separate from the roof so that they can be removed and stored on edge. In areas with regular heavy snowfalls, the snow lessens the chance of solar insulation damage. However, in most cases, lath can safely be left up all winter to positively prevent it. Even if lath on the roof of a shadehouse is removed, the walls should be left up to protect the trees from high winds. There is no standard for shadehouse construction. Wood construction is traditional and is usually viewed as more permanent than shade cloth houses. Wooden shadehouses must be well constructed, not only to support their own weight and snow loads, but also to prevent unsightly sagging and bowing of the lath an other structural members as the house ages. Frame work designs for shadehouses vary from stretche wire and posts to post and beam wooden and stee frames to metal bow-arches. There seems to be n clearcut advantage to any type of shadehouse frame So, the selection should be made for least cost, utilit for a given operation, and appearance.

Spice (1977) describes an innovative shadehous constructed at moderate cost. It consisted of a serie of parallel wires streched over the area to be shade Small pieces of black polyethylene sheeting (about by 12 inches) (7.5 × 30 cm) were lapped over eac strand of wire and tied to the wire using an overhan knot so that the two ends of the strip hang verticall down. As many strips are tied to each wire as roo permits. The result is a shadehouse providi mottled shade that is highly resistant to win damage. Construction is labor intensive, bu materials needed are inexpensive.

8.4 Using Shadehouses

Seedlings are often stored over winter in shad houses. This allows crops grown in one season to l held for spring planting the following season withou occupying greenhouse space all the while. Whe greenhouse space is available for such storage, it the most protective alternative and should be use In the Pacific Northwest, a protective roof is desi able for overwinter storage of trees to prevent ove watering from rain and the resultant root-rot pro lems. Overwinter storage of trees in shadehouses Pacific Marine climates is not desirable, but can l done. Containers should be placed on boards pallets to allow for drainage and air circulatio During cold weather, the borders of groups of co tainers may have to be insulated to prevent ro damage. In cold weather, warm air or water ma have to be circulated below the roots to preve freezing damage.

In the interior West, shadehouse storage of see lings over winter is more practical. Containe should be placed flush on the ground and co centrated. The border of each grouping should insulated with sawdust, chips, or bark to provi insurance against damage to the roots of the plar from extremely low temperatures. Snowfall normal will not damage the trees.

In summer, container blocks in lathhouses are be spaced apart to allow for air circulation and lig infiltration through the crowns. Blocks must elevated to allow free air circulation underneath allow air pruning of the roots (i.e. root tip exposu to air and resultant dessication). Container bloc are often placed on boards, pallets, or benches enhance air circulation.

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[1] *Personal communication with Dr. Peyton W. Owston, Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg., June 1978.*

8.5 Shadehouse Irrigation Systems

The irrigation system in a shadehouse can be fixed r portable. Portable aluminum pipe with impulse orinkler heads on risers is often used. Complete overage and as much uniformity as is practical nould be assured. Fixed systems should be conructed so that the irrigation system will not obruct production operations. The most efficient way fertilize seedlings is through the watering system, ist as in the greenhouse. To do this, provision can ometimes be made at the nutrient injector for lumbing to the shadehouse. In some cases, a parate nutrient injector is the logical answer. Most the precautions stated in section 6.4 relating to eenhouse irrigation systems apply to shadehouse ystems. However, shadehouse sprinklers can water ne trees at higher rates and with coarser droplets, ecause the trees are bigger. This allows effective irriation in windy conditions. Also, shorter irrigation eriods mean seedling foliage is soaking wet less of ne time, lowering the chances of disease infection.

8.6 Shadehouse Floors

The floor of the shadehouse can be gravel, asphalt, r cement. Gravel is commonly used because it is neap, readily available, and porous, but weed ontrol on a gravel floor is necessary. Asphalt and concrete are more expensive and are nonporous. When using any of the three materials, the developer must properly crown the area and provide for drainage of excess water. Cement or asphalt are used where a hard surface is required.

Shadehouses should be positioned for efficient flow of seedlings from greenhouses to shadehouses and from shadehouse to delivery trucks. This consideration is part of initial site planning.

8.7 Size and Number of Shadehouses

The size and number of the shadehouses depends on the production scheme. Are all trees grown to be in the shadehouses part of the time, only part of them, or will the shadehouses hold just special products? This is determined in the production scheduling associated with greenhouse sizing (see section 5.3). Size of the shadehouses relative to the number of trees to be held is an open question. A general rule is shadehouses should have about one-third more floor space than the trees would require in the greenhouse. The added space is used for aisles and for spacing containers apart for air and light infiltration. This is a guide for approximate estimation of needs. Exact figures are easily developed diagrametrically using the number of trees involved, the spacing of the blocks, and the materials handling system to be employed.

SECTION 9.—CONTAINERS AND GROWING MEDIUM

9.1 Function of Containers

9.2 Container Concepts and Types

9.21 The Basic Types of Containers

9.22 Container Characteristics

9.23 Containers Planted with the Tree

9.24 Containers Not Planted with the Tree

9.25 Containers Available by Manufacturer

9.26 Summary and Discussion

9.3 Growing Media

9.31 General Discussion

9.32 Growing Medium Components

9.33 Media Mixes and Mechanics of Aeration and Drainage

9.34 Preparation of Growing Medium

9.35 Commercially Prepared Growing Media

9.36 Addition of Fertilizer and Mycorrhizal Fungi to Medium

9.37 Growing Medium Sterilization

SECTION 9.—CONTAINERS AND GROWING MEDIUM

9.1 Function of Containers

Biologically, the function of containers is to:

1. Provide a medium for support and nutrition of the roots.
2. Protect the roots from mechanical damage and desiccation.
3. Shape the roots into a form advantageous to the tree.
4. Maximize field survival and early growth, because the root system is not disturbed but remains in intimate contact with the growing medium.

Operationally, the function of containers is to package the seedling into a standard size and shape for ease of handling throughout the nursery, shipping, and planting phases.

Recently, a great deal of concern has been expressed about the root form of planted trees (van Eerden and Kinghorn 1979). There is no question that planted trees, bare-root or container, have a different root configuration than trees grown from seed in place. In some instances, windthrow of plantations has been traced to poor root development. Pines of all species seem to be particularly susceptible. Two problems seem to be most important. When the tree is planted, roots must not be allowed to remain in a circle around the central axis. As they grow in size, they will eventually restrict diameter growth of the tap root. Even if the circling roots graft and fuse with the tap root, a weak spot is created as the ster
diameter above continues to enlarge. The tree ma
suddenly break at the root collar in a high wind
The other problem is lack of an adequate numbe
or distribution of lateral roots near the surface. Th
container must be designed to overcome these tw
problems.

In horticulture, the term "container" signifies wh
most forest tree nurserymen would call a "pot
meaning a cylindrical or rectangular plant containe
slightly smaller in diameter at the bottom than th
top, with a depth not much greater than th
diameter, and having a flat bottom. Containers
this type are referred to by the volume they displac
They are made of fired clay, metal, plasti
compressed wood pulp, or peat.

When forest tree nurserymen refer to "container
they mean "a container designed specially for th
growth and culture of tree seedlings."

The shape of these small containers is very muc
different from the usual nursery pot. CTS containe
are usually much deeper than their top diameter (
much as 10 times). This is because, in ma
instances, forest tree seedlings produce tapro
systems rather than fibrous root systems, and
narrow, deep container is more compatible with th
growth habit. Second, in wildland plantings, it
desirable to place the roots as deeply as possible in
the soil where moisture will be available the longes
Third, planting holes of necessary depth are easier
punch or auger if the hole has a small diamete
because less earth must be moved and there is le
compaction.

9.2 Container Concepts and Types

Basically, the theory of containerized tree seedlings that, if a tree seedling can be planted with a inimum of root exposure and disturbance, there ill be less transplanting shock, and survival and rowth rates will be higher (Kinghorn 1974). The esign of all containers is intended to minimize this ot disturbance.

.21 The Basic Types of Containers

here are two approaches to container design:

1. The container is planted with the tree. Provision is made for root egress from the container by its biodegradability, or through holes, slots, and expandable seams built into the container.
2. The tree and its plug of rooting medium held together and in shape by the tree's roots are removed from the container and then planted. The container is not planted, but may be either discarded after a single crop, or reused, depending on the type.

Each of these approaches has inherent advantages nd disadvantages. In North America, most of the ontainer seedlings are grown in rigid-wall containers at are removed from the tree when it is planted. ne advantages of this concept are:

1. In the nursery, it is fairly easy to prevent tree roots from growing from one cavity to the next. When it occurs, this results in root breakage, disruption of contact between growing medium and roots, and greater physical effort to extract the plug from the container.
2. The container can be reusable, which lowers its unit cost per tree.
3. The shape of the container can greatly affect future growth of the seedling in the field (section 9.22). Most rigid wall containers incorporate vertical ribs or grooves, rounded horizontal corners, and a bottom hole for root egress, which successfully prevents lateral roots from circling around the central axis, provided the tree is outplanted on schedule. (Trees can become rootbound in even the best container, if they are held too long).
4. When planting, removal of the container instantly eliminates any barrier to root egress caused by the container. (There may still be a barrier caused by difference in properties between the growing medium and soil, however).

e disadvantages are:

1. The root ball must be removed from the impermeable walled container. This operation is not necessary when the container is planted with the tree.
2. To be reused, the container must be returned to the nursery, cleaned, and sterilized. This is a nuisance, and many damaged containers will not be reusable.

There are several types of containers designed to be planted with the tree. The new Walters' square bullet (fig. 9-1) and ITW One-way® (fig. 9-2) are not degradable, have impenetrable walls, and have the root control features mentioned above, but the walls do not interfere with root egress. This is because the walls of the bullet are intended to come apart into four pieces as the tree grows, and the One-way® has a removable sleeve.

Most containers designed to be planted with the tree are degradable. These are particularly desirable in concept, because they involve less handling and have the potential to produce a more natural form of root system than current, impermeable walled, containers (fig. 9-3). However, the currently available types have three major disadvantages:

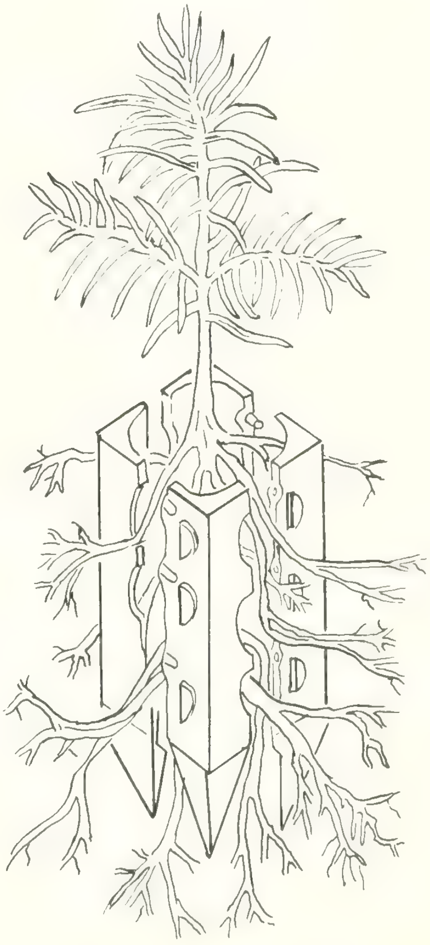


Figure 9-1.—Walters' square bullet showing radial separation of bullet sections caused by force of root growth (Walters 1974).

1. When the container wall remains impermeable to roots through the nursery phase, it will usually continue to restrict root growth after outplanting. If free root egress after outplanting is possible, the container has probably disintegrated to the point that it is difficult to handle in shipping and planting.
2. If root egress from one container to the next has occurred in the nursery, roots will be broken and lost when the containers are separated. Small seedlings, with weak or unlignified roots, will separate cleanly, but large ones will not without considerable effort and root damage.
3. Degradation rate and root penetration is critically dependent on adequate moisture. This type of container cannot be recommended for dry sites.

9.22 Container Characteristics

There are numerous other characteristics of containers that affect their use. Many of these characteristics affect the way they interact with the tree seedlings grown in them.

Volume.—The volume of rooting medium the containers will hold varies. The largest CTS containers are in the 45-cubic-inch (700-cm^3) range, while the smallest are approximately 2 cubic inches (30 cm^3). Container volume is directly related to the size of seedling desired.

Shape.—Containers may be round, hexagonal, rectangular, or square in horizontal cross-section. The ratio of depth of container to surface area at the top of the container also varies, as does the structural rigidity of the unit.

Taper.—Some containers are tapered (become progressively smaller in cross-section from the top to the bottom), and some are not. Some are tape only over a portion of their length, often near bottom of the container.

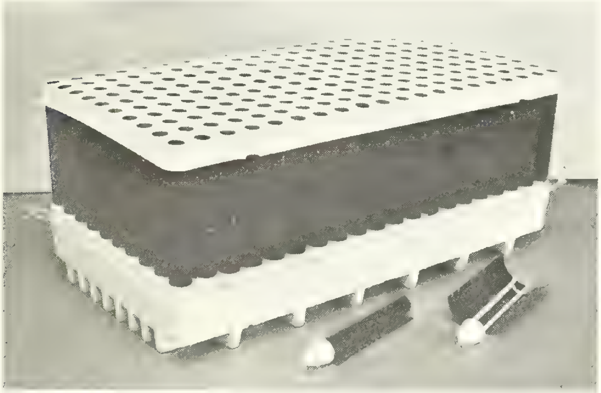


Figure 9-2.—ITW One-way® as the block comes ready to fill and seed. In the foreground, individual containers intact, and with the outer sleeve removed.

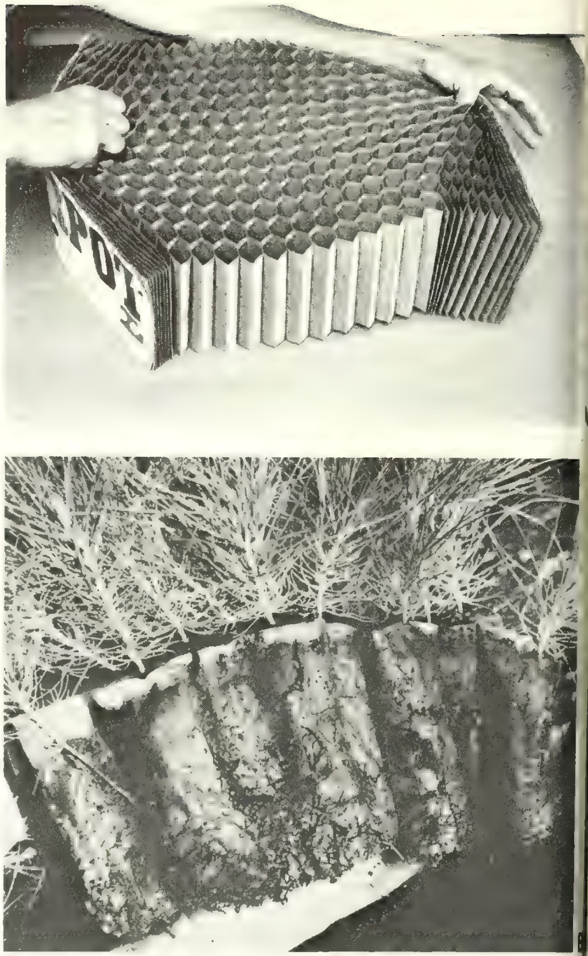


Figure 9-3.—Paperpot as it comes from the manufactu before filling (A) and after the seedlings are grown (B).

Root control.—As mentioned in 9.21, contain can produce malformed root systems that ca windthrow and breakage later in the life of the t (Donald 1968, Ben Salem 1971). In general, contai shape controls root system configuration (Hiatt a Tinus 1974). Most of the widely used contain designed for CTS growing now incorporate featu such as vertical internal ribs to reduce root spirall in the container and possible future strangulat problems. These ribs, ridges, or grooves direct roots to the bottom of the container where they air pruned. Use of a properly shaped container root control for a proper length of time should res in few root spiralling problems. Kinked roots a container compression of roots can be expected some containers (Carlson and Nairn 1977).

Root egress opening.—All CTS containers urrently in use provide an opening at the bottom or root egress to prevent root balling in the bottom f the container and allow excess water to drain out. his opening can be as large as the cross-section of he container or somewhat smaller. Because the ertical ribs and rounded horizontal corners direct rowing root tips to the bottom of the container, the gress hole must be large enough to accumulate a rge number of roots without plugging and causing he growing medium to waterlog. The hole should be s large as possible, but still prevent loss of the rowing medium.

Construction material.—The container is usually ade of plastic or paper. The strength, thickness, urability, and other structural features vary considrably, depending on the intended function and use f the container. All share one characteristic: they ust be impermeable to the seedling's roots while the ontainers are at the nursery. Otherwise, the seedling ill lose part of its root system when removed from he container or when the containers are separated Tinus 1974d).

Unitization.—Some containers are freestanding nits that can be used alone, some require a supportng rack system to keep them upright and properly aced, and others are simply a cavity formed in a rger unit or block and cannot be separated from the rger unit. Each approach has certain advantages nd disadvantages.

System design.—The nature of the container unit elected can have profound effects on the design of he greenhouse container handling system and the enches used. Where a variety of containers are to be sed, the handling methods and bench system must e flexible. The container unit used also will affect edling packaging, shipment, storage, and planting ethods. In some cases, the container is part of a rger growing, handling, and planting system esign.

Density.—Depending on container configuration nd size, there will be a certain number of containers n a given area of bench space. This establishes the umber of containers that can be placed on the enches of a greenhouse. This is illustrated in section 3. In general, as containers become progressively rger, the trees that will be grown in them will be of rger shippable size. These larger trees will have rger tops, and the containers must be spaced rther apart, otherwise, the seedlings will compete r light, resulting in slower growth and spindly tops.

9.23 Containers Planted with the Tree

This type of container can be divided into two categories:

Those filled with rooting medium.—These include tar paper pot, the Conwed® open mesh plastic tube, the Alberta peat sausage, the Walters square bullet, and various paper pot systems. In these systems, the container is filled with medium, the tree is grown in the container, and the container is then planted with the tree. The container is either degradable or has openings that allow for root egress as the tree develops after planting. Degradable pots are advantageous, because the roots are not disturbed during shipment and planting (section 9.1.) Operationally, the use of the same unit all the way through the growing and shipping process is efficient. The container protects the root system from mechanical damage and from exposure to drying and temperature extremes. Theoretically, the root-soil interface is never disturbed. Ideally, the walls of the container restrain root penetration and remain structurally sound up to the time of planting, then degrade rapidly after planting to allow free root egress and free exchange of water and nutrients between the root plug and the native soil. However, because of variations in the degradation rate of the container, roots often penetrate the walls of the container before they should, or the structural integrity of the container breaks down too late or too soon. If either occurs, the advantage of using degradable containers is quickly lost. Considerable effort has been expended by manufacturers of degradable containers to control the degradation rate (Clendinning et al. 1974). Some paper pots have components incorporated in the paper that provide differing rates of degradation.

Containers planted with the tree that depend less on biodegradability than mechanical expansion or openings for root growth and egress are available in several forms. With pines especially, the major problems with these types of containers are (1) roots intertwine between containers during culture in the greenhouse, and (2) root development is restricted after outplanting in the field (section 9.1). Advantages of the other plantable containers also apply to these types.

Plantable containers not filled with rooting medium.—In some cases, the container is a molded block of growing medium without a wall. Some examples of this type of container are Polyloam® Tree Start® and BR-8 Blocks® (fig. 9-4). The biggest potential advantage of these containers is that there is no need to mix and load a separate rooting medium into a container shell. The other advantages of containers planted with the tree also apply. There is no chance for root binding in the container, because there is no wall. However, roots can readily pass from one container to the next, unless impenetrable dividers are used. The containers then may be hard to separate without damage to the root system. The premise is that such containers will be planted just as roots emerge from the container, so, timing becomes critical as it does with the walled degradable units.

The container is made of various materials including peat, wood pulp, and plastic foam and fiber. The chemical and physical properties of the material can be regulated in the manufacturing process to produce a substrate suitable for plant growth. Control of the growing medium formulation is left to the container manufacturer. This may result in a loss of flexibility. These manufactured substances normally harbor no diseases, insects, or weed seeds.

9.24 Containers Not Planted with the Tree

In 1979, it is most common to remove the tree seedling with its cohesive plug of roots and growing medium from the container before outplanting. Removal can take place at the nursery before the seedling is shipped or in the field just before planting. In such systems, it is essential that the roots of the tree hold the rooting medium together so that the plug retains its structural integrity and shape. This is essential not only to minimize root disturbance and exposure between removal of the root plug from the container and planting, but also so that the plug will conform to, and fit snugly in, the hole prepared for it in the soil. As a consequence, the degree of root development at planting time is critical. The seedlings must be removed and planted when the roots are ready for rapid egress to avoid potbinding (Kinghorn 1974). The plug-like appearance of the roots plus growing medium of seedlings properly grown in these containers, combined with the fact this matrix is "plugged into" a dibbled planting hole, is the reason these containers are called "plug containers" or "plug systems."

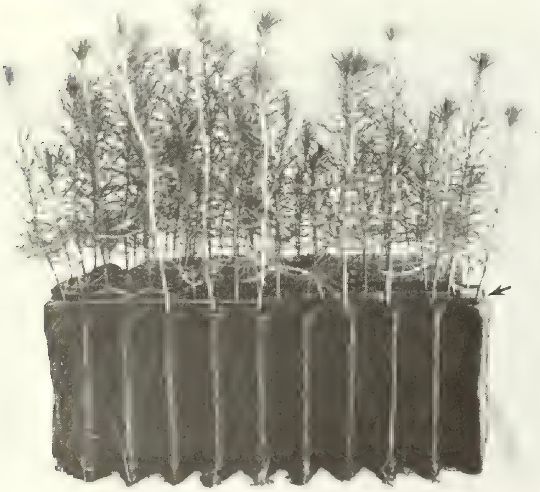


Figure 9-4.—Tree Start® is a molded block of growing medium, mainly peat. Polyethylene strips prevent roots from crossing from one row to the next. (Photo courtesy of Keyes Fibre Co.).

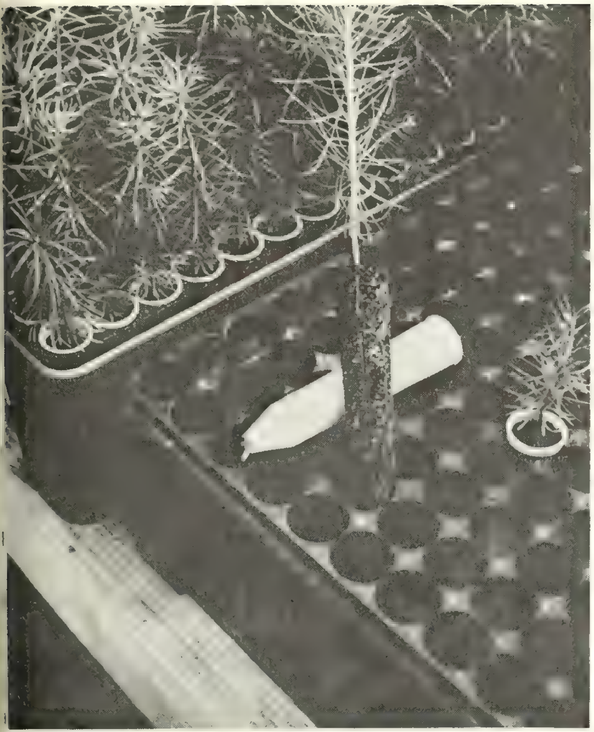
Common characteristics of plug containers.—Good plug containers have the following characteristics:

1. The seedling must be easily removable from the container.
2. The container walls are impenetrable by the seedling roots. In properly designed containers, there is no possibility of intertree entanglement.
3. The containers are lightweight to facilitate handling and transport.
4. The containers are constructed of sterile, essentially inert material.
5. Because of the impenetrable container walls, there should be some feature, such as vertical internal ribs, to prevent root spiralling and possible future root strangulation. Such ribs or grooves conduct the roots toward the drainage hole at the bottom of the container.
6. Containers that taper from the top to bottom produce a root plug that is pointed or somewhat bullet-shaped. The plug then fits tightly into a hole created with a pointed planting dibble of similar shape; a desirable feature.
7. When the plug is removed from the container and planted, there is no container barrier at the plug-soil interface.

Container systems or any other new reforestation technique must yield biologically acceptable results as well as be suitable for mechanization (Kinghorn 1970). All systems typically are a compromise between operational or mechanical and biological goals. For simplicity, three general approaches called "cell," "block," and "book" designs, are explained below.

Cell designs.—A cell is an individual containe unit. Although it may be unitized in trays or racks for handling, each seedling is in a container that can be separated from the others (Allison 1974). Th most prominent example is the Leach Cone-tainer® (fig. 9-5). Cell containers are usually made of polyethylene.

For nursery operations, the individual cells are usually placed in special racks or trays to hold them upright and in place. The holder or rack for the cell determines spacing between cells and the resultant density of cells per unit area.



igure 9-5.—The single cell system consists of separate containers and a rack to hold them.

An advantage of single cell plug container design is iat the cells can be handled either singly or as a unit f 100 or more. If, in the growing process, a certain umber of cells do not develop actively growing edlings, the empty cells may be removed and placed with cells with a tree. This way only good ees are kept in the holder, and maximum bench pace can be utilized. Also, if more growing space is esired per tree, the spacing between the cells can be creased rather easily by removing every other cell. his strategy works well in operations where greenouse space is at a premium. It is not a big advantage extensive operations where low labor intensity is aramount. This is offset to a degree by the fact that ch cell must be handled individually when loading cks or cleaning recycled cells.

It is possible to remove the seedlings from the cells the nursery and ship only the plugs to the field. ne advantage is that the container is not shipped ith the tree. Since nearly all cell and block container its are designed to be used for more than one crop, is prevents losses and damage to the containers in ipping and in the field. However, since all mechanal protection for the seedlings is removed and its ntainer-plug interface is disrupted, a different ckaging method must be substituted for the cell or ock to protect the trees and keep the plug from ying out before planting. The trees must be ndled carefully at all stages of this process to eserve plug integrity.

With cell systems, it is common for the seedlings to be sent to the field in the containers. Usually, but not always, the cells are removed from the holders or racks, culled, bundled, and packaged in cardboard boxes for shipment to the field. This reduces the space needed to ship a given number of seedlings (fig. 9-6). Seedlings are extracted from the container in the field just before planting. The cells are saved and returned to the nursery for cleaning and reuse.

With both cell and block systems (discussed below), extracting the seedlings from the cavity is a nuisance. Under the best of conditions, it is time consuming. In the field, it cuts tree planter's production by requiring extra motions in the planting process. The proper development of the root system and the proper moisture content of the plug are important to easy plug extraction. The nature of the container walls and the number and height of root control ridges in the cavity also play a part. Some kneading of cells made of pliable plastic or knocking the container gently against the hand or other object usually facilitates extraction.

Block design.—Blocks are a group of individual cavities or cells that are permanently attached to each

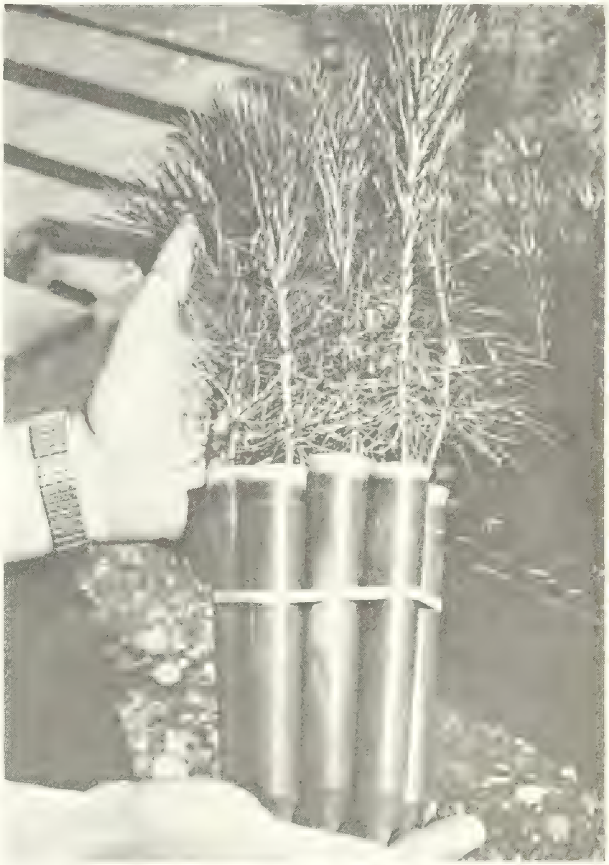


Figure 9-6.—Ponderosa pine grown in single cells and bundled for packing. A rubber band holds the cells together.

other. Examples are the Styroblock® and the Multipot® among others (Sjoberg 1974 and Wood 1974). Styroblocks (fig. 9-7) are formed from expanded bead polystyrene with various sized cavities for different species and sizes of trees. The Multipot® (fig. 9-8) is similar, except it is molded of high density polyethylene. The advantages of these units are:

1. Cavities and block are all one rigid, lightweight unit about the right size to handle.
2. The cavities are always in the same position in the block and cannot come loose or fall out. There are no cells to have to handle individually.
3. The material in polystyrene bead formed blocks provides insulation from temperature extremes for the root systems of the trees.

The disadvantages are:

1. The trees must be extracted without kneading or jarring the container. However there have been few extraction problems with this type of container.
2. The containers must be sent back to the nursery, if they are sent to the field—a problem in common with all recycled containers.
3. Cavities where no tree develops must have seedlings transplanted into them or remain blank. Sowing more than one seed per cavity and then thinning excess trees tends to offset this problem.
4. Damage to the block, beyond a certain degree, results in loss of the whole block, even if most of the cavities are still intact.

Trees are sometimes removed from the blocks at the nursery, packaged, and then sent to the field. The blocks then remain at the nursery, which helps preserve the containers and returns them quickly to production, but the seedling plugs are more susceptible to damage. Removal of plugs from the blocks has some advantages:

1. It allows grading of stock and elimination of blank cavities.

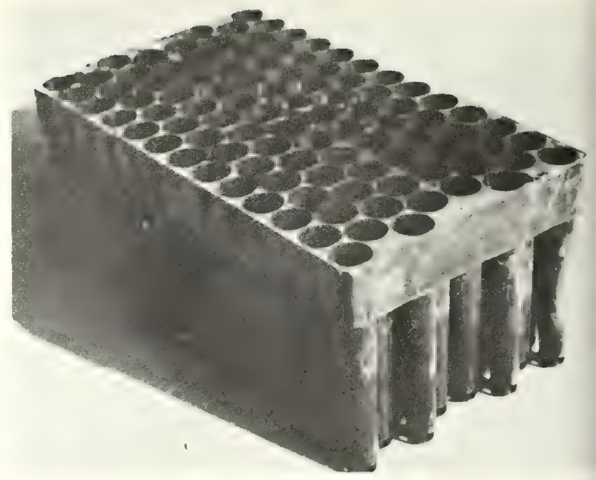


Figure 9-8.—The Crown Zellerbach Multipot.

2. It reduces shipping volume, usually by mor than half.
3. It obviates the need for recycling the containe from the field and eliminates damage to cor tainers in shipment and field use.

The procedure used in British Columbia (Sjober 1974) has been to extract seedlings by hand and wra in bundles of 25 in stretchable PVC film commonl used for produce and meat packaging. The bundle are placed in waxed cartons in an upright position fc truck transport (fig. 9-9).

Nearly all block container designs incorporate roc control ridges in the inside of the cavity. Some of tl blocks are specially sized and adapted to nurser benches and conveyors to facilitate handling— reflection of the fact that the modular block desig lends itself well to machine handling and mec anization.

At least one block system (the Hahn Quarterblo System) allows for the block to be broken down in smaller unit blocks to facilitate field handling of tl trees. Four of these "quarterblocks" are then rea

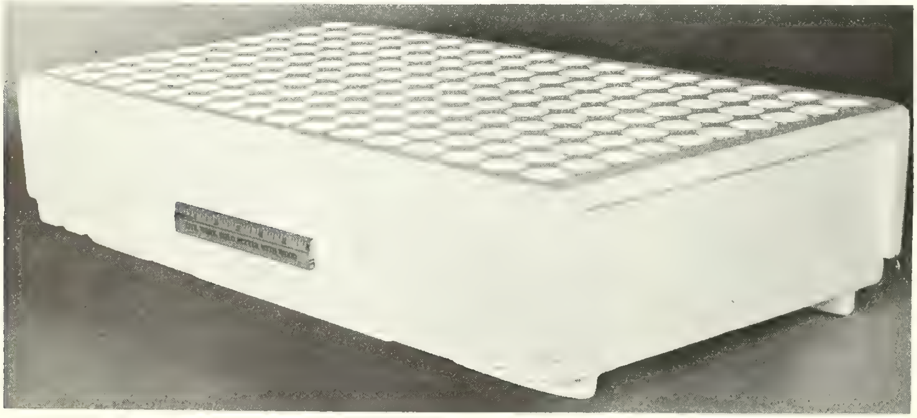


Figure 9-7.—BC/CFS styrobloc

igure 9-9.—Seedlings are extracted from the container, wrapped in bundles of 25 (A), and placed upright in waxed cartons for shipment (B).

mbled with tape into a larger "nursery" block to cilitate nursery production (Hahn 1976).

Book designs.—The term "book" denotes those ıntainers thermoformed from thin polystyrene eet plastic to produce a row of cavities when each ırtion is assembled. These may have a plastic hinge the bottom, as do the Spencer-Lemaire Rootrains® (fig. 9-10A) so that one piece of formed plastic is lded like a book to form the cavities (Spencer '74). The Tubepak® is another book system, but o pieces of formed plastic snap together. When sembled, book planters form three to six cavities, ore or less rectangular in cross-section, which taper at the lower end to a root egress hole, and have numerous internal ridges to control root orientation and prevent root spiralling.

Book planters must be held together in specially designed trays or with tape, glue, or straps to form units that are multiples of individual books (fig. 9-10B). When such units are assembled, the books are filled with rooting medium and seeded. The thin

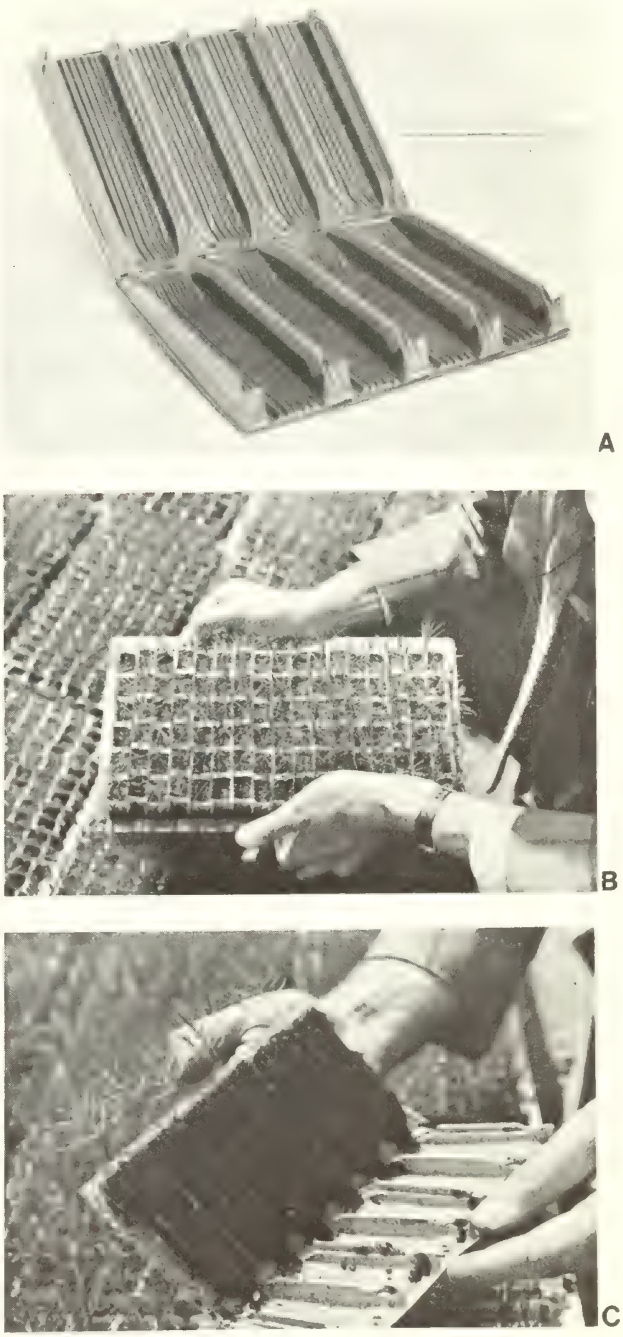


Figure 9-10.—Spencer-Lemaire Rootrainer unit (A), assembled into a block (B), and opened for inspection or to remove seedlings (C).

plastic shells of these containers are generally intended for one crop use. The material usually begins to become brittle near the end of a long growth period (9 months). In the South, where crops are reared 10-12 weeks, the books may be used one or two more times, however.[1] In the field, the book is opened by removing or folding back one side, and the plugs lifted out (fig. 9-10C).

Some advantages of book designs are:

1. The tree is sent to the field in the container.
2. If the container is discarded when the trees are planted; no return to the nursery is necessary.
3. When new containers are always used at the nursery there are no recycled containers to handle or clean for the next crop.
4. Plugs are quickly and easily extracted.

Some disadvantages of the book containers are:

1. The containers must be assembled before loading.
2. The container units require a frame, tray, gluing, or taping to form a unit for handling and shipment.
3. The container is generally used only once, which tends to make it expensive per crop.
4. Blank cavities must be reseeded or have germinated seed transplanted into them to avoid blanks.

9.25 Types of Containers Available by Manufacturer

During the past several years, the numbers and types of containers specially engineered and produced for tree seedling culture have grown considerably. At present, the types and designs appear to be stabilizing, but continuing development work is apparent. Thus, any compilation of container types and manufacturers tends to become obsolete rapidly. The latest, and most complete compilation, by Venator (1975), with some additions by the authors is reproduced in table 9-1.

9.26 Summary and Discussion

Each type of container has advantages and disadvantages in actual use. The selection of the particular size and type of container to use is determined by a number of factors. In the early stages of CTS program development, it is often best not to select any one size or type of container, unless considerable evidence indicates it is the size and type necessary for planting success. Such information is usually not available early in a program, so, container selection is based largely on experience and the developer knowledge of the market or local field plantin requirements.

The developer should test a number of contain sizes and types, if possible. In this way, the contain best fitting the situation from operational an biological standpoint can be determined. Consi erable field testing with different containers may necessary before sufficient reliable data on plantin productivity, nursery production costs, and cost p surviving seedling, is available to permit decision. general:

1. The best container type and size combination that which will produce an established, rapid growing seedling at the minimum cost per tre In severe climates or very brushy areas, th may mean a very large tree. In ideal situation a small tree may do equally well. The small the container and tree necessary, the cheaper will be produced at the nursery. This is becau more trees can be produced per unit area greenhouse space, and each crop will be in t house a shorter time.
2. Until the best container system and tree size determined, it is generally unwise to purcha sophisticated loading and seeding equipme which can handle only one or two types of co tainers. The equipment options should rema flexible until a definite type of container a container size is selected. Some loading a seeding equipment allows for such flexibili other types do not.
3. There is no ideal container, but there is usua a best one for a given production and planti situation. This best size and type can be det mined by operational cost collection a planting survival and growth results. Where variety of planting conditions are expect along with different packaging and transp problems, several container sizes and ty may offer the optimum solution.
4. Most of the containers on the market today good, but container development is continu and even better ones can be expected in future. For instance, when a plug seedling outplanted, most of the new roots develop fr the accumulated growing points at the bott of the plug. Many species, especially pi produce few roots close to the surface. possible improvement over currently availa rigid wall containers would be to provide h or slits in the side of the containers and sp the containers apart sufficiently to air prune roots at these openings. A tree grown in suc container should produce lateral roots clos the surface from the growing points develo at the slits. It should develop a balanced, m

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[1] *Personal communication with O. C. Goodwin, North Carolina Division of Forest Resources, Raleigh, N.C., May 1978.*

Table 9-1.—Manufacturers or distributors of containers suitable for growing forest tree seedlings.

Supplier	Common name of container	Container material	Container volume (cm^3)	Biodegradable properties	Root egress
gritec Co. Inc. 939 D Milwee ouston, Tex. 77018	Polyloam Tree Container	Nutrient enriched synthetic base material	20-37	Slowly	Yes
eaver Plastics, Ltd. 2806-63 Street dmonton, Alberta anada	Styroblock	Polystyrene foam	35-120	No (reusable 2-3 times)	No
etter Plastics, Inc. 206 N. Main Street issimmee, Fla. 32741	Test Tube	Polyethylene	Variable	No (reusable)	No
righton By-Products . O. Box 23 ew Brighton, Pa. 15006	Kys-Kube	Organic-inorganic mixture	20-25	Yes	Yes
righton By-Products . O. Box 23 ew Brighton, Pa. 15006	0-903	Phenol formaldehyde with residual phosphates, nitrates, and soda ash	20-30	Slowly	Yes
olorado State Nursery oothills Campus olorado State Univ. ort Collins, Colo. 80521	Tar Paper Pot (Containers are not commercially available; however, blueprints for production systems are available upon request)	15 pound tar paper	Variable	Slowly	Yes
olumbia Plastics, Ltd. 155 West 10th Ave. ancouver, British olumbia, Canada	Modified Walter's Bullet	High impact polystyrene	15-10	No	Yes
onwed Corporation 42 29th Ave. SE inneapolis, Minn. 5414	Conwed Open-mesh plastic tubing	Plastic webs	Variable	No (products under development)	Yes
dmonton Nurseries, d., 13332-13th Ave. dmonton, Alberta anada	Peat Sausage or Easy Root Container	Low density polyethylene filled with peat	Variable	Slowly	No
amco, Inc. 0 Lake Road edina, Ohio 44256	BR-8	Modified cellulose fiber	20-30	Yes	Yes
ASPRO, Inc. 05 Kamehameha Hwy. onolulu, Hawaii 96819	Hawaii Dibbling Tube	Polyethylene	30	No (reusable)	No
een Thumb Products rp., Drawer 760 opka, Fla. 32703	Rack Substratum System 73	Natural and synthetic fibers	Variable	Yes	Yes
inois Tool Works -Cone Division 40 Bryn Mawr Ave. aska, Ill. 60143	One-Way	Molded polystyrene and polystyrene sheet	60	No	Yes
fy Products of nerica, P.O. Box 338 est Chicago, Ill. 60185	Jiffy-7 peat pellets, strips, and pots	Peat	20-40	Yes	Yes
eyes Fibre Co. orticultural Div. epartment X ew Iberia, La. 70560	Kys-Kube	Organic-inorganic mixture	20-25	Yes	Yes
nnen Tehtaat Oy perpot Department -27820 ISO-VIMMA nland	Paperpot Method, Special Paper for the Paperpot Method, consulting service in nursery planning (European distributor)		10-650 (approx. 20 different sizes 3 different qualities)	Yes	Yes

Table 9-1.—Continued.

Supplier	Common name of container	Container material	Container volume (cm^3)	Biodegradable properties	Root egress
Lannen Tehtaat Oy Paperpot Department SF-27820 ISO-VIMMA Finland	NISULA Roll Plant Method Transplanting machines (European distributor) (For above 2, see also Reid, Collins and United Asia)	Polyethylene film	Variable	No	No
J. M. McConkey Co., Inc. P. O. Box 309 Sumner, Wash. 98390	Plug Tray	High density polyethylene	140	No	No
J. M. McConkey Co., Inc. P. O. Box 309 Sumner, Wash. 98390	DEEPOT	High density polyethylene	656	No	No
Micro-Plastics Co., Ltd. P. O. Box 844 Guelph, Ontario, N1H 6M6, Canada	Ontario Tube	High impact polystyrene	Variable	No	No
Poly-cast Plastics Route 2, Box 706 Beaverton, Oreg. 97005	Cone-tainer	High density polyethylene	Variable	No (reusable)	No
Reid, Collins and Associates, Inc. Reforestation Division 550 Burrar Street Vancouver, Canada V6C 2K6	Paperpot Method Equipment for the Paper Method, consulting service in nursery planning (Canadian distributor)	Special paper	10-650 (approx. 20 different sizes, 3 different qualities)	Yes	Yes
Rex Packaging, Inc. P. O. Box 18257 Jacksonville, Fla. 32229	Polypot	Polyethylene coated paper	200 (square dimensions)	Slowly	No
Silvaseed Company P. O. Box 118 Roy, Wash. 98580	Styroblock (USA distributor)	Polystyrene foam	35-120	No (reusable 2-3 times)	No
Spencer-Lemaire Industries, Ltd. 9160 Jasper Ave. Edmonton, Alberta Canada	Rootrainers (Equipment for Rootrainers Method also available)	Polystyrene	30-340	No (perhaps reusable)	No
Tree Tech. Inc. P. O. Box 86 Mason, Mich. 48854	Plant Bands	Paper, polyethylene coated or not	Any size	Yes	Yes
Tri-State Mill Supply Co. P. O. Box 220 Crossett, Ark. 71635	Styroblock	Polystyrene foam	35-120	No (reusable 2-3 times)	No
Tubepak 402 East 900 South Suite 2 Salt Lake City, Utah 84111	Tubepak	Polystyrene	280	No (perhaps reusable)	No
Union Carbide Corp. Chemicals and Plastics Div., River Road Bound Brook, N.J. 08805	—	Polycaprolactone	Variable	Yes (currently in experimental stages)	Yes

Table 9-1.—Continued.

Supplier	Common name of container	Container material	Container volume (cm^3)	Biodegradable properties	Root egress
United Asia Trading Co. 3840 Crenshaw Blvd. Los Angeles, Calif. 90008	NISULA Roll Plant Method Transplanting Machine (USA distributor)	Polyethylene film	Variable	Yes	No
United Asia Trading Co. 3840 Crenshaw Blvd. Los Angeles, Calif. 90008	Paperpot Method, Equipment for the Paperpot Method, consulting service in nursery planning (USA distributor)	Special paper	10-650 (approx. 20 different sizes, 3 different qualities)	Yes	Yes
Western Pulp Products Co., Box 968 Corvallis, Oreg. 97330	Fiber pot	Wood pulp	Variable	Yes	No (but roots penetrate pot)

windfirm root system more like that of a natural seedling and devoid of detrimental root configurations. In addition, fewer growing points should accumulate at the bottom, which would permit using a smaller bottom hole in the container.

9.3 Growing Media

.31 General Discussion

"Growing medium" is by no means as standard a rm as "container." Other terms used synonymously e "rooting mix," "pot mix," "growth medium," oil mix," and "potting mix." It is the material that ls the containers and performs the same function r the seedling as soil does in the field. The term nix" is used in a number of the terms synonymously ith medium, because it describes the medium to be mixture of substances. This is usually, but not ways, the case. The term "growing medium" will be ed here because it is probably the most general rm and least likely to cause confusion.

Many materials can be used as a growing medium, ch as sand, compost, peat, sphagnum moss, rmiculite, topsoil, and some synthetic materials, it for functional and economic reasons, peat-rmiculite mixtures predominate (Phipps 1974). atural soil is not used as a CTS growing medium, cause other media have more desirable physical aracteristics (i.e., water holding capacity, ration, and bulk density). Also, natural soil and nd are too heavy for CTS products that often have be carried over precipitous terrain to the planting es. Ground bark is used as a medium by a few owers, especially where it is readily available.

For CTS operations, peat-vermiculite mixes are most widely used for several good reasons. When properly prepared:

1. They are lightweight—a consideration of some importance in forest planting, as well as nursery operations.
2. They are uniform in composition, relatively inexpensive, and readily available.
3. They are relatively free of insects and diseases.
4. They have a high cation exchange capacity per unit dry weight compared to ground bark or sandy loam soil.
5. They have a high water holding capacity, so, the frequency of irrigation and fertilization is reduced compared to sandy soil.
6. In most instances, they provide an acid growing medium, conducive to conifer growth.
7. When the peat and vermiculite are in proper proportions, they yield a medium that is well aerated and drained while still holding substantial quantities of water that is readily available to the plant.

In some cases, a spongy volcanic material called "perlite" is used in place of the vermiculite. This is also acceptable. Both materials are used to increase the aeration and drainage capability of the peat.

9.32 Growing Medium Components

A good growing medium should have the following characteristics (Richards et al. 1964):

1. The medium must be sufficiently firm and dense to hold the cuttings or seeds in place during rooting or germination. Its volume must be fairly constant when either wet or dry. Excessive shrinkage upon drying is undesirable.

2. It must sufficiently retain moisture so that watering does not have to be too frequent.
3. It must be sufficiently porous that excess water drains away, permitting adequate aeration. This is crucial in conifer tree culture.
4. It must be free, or nearly so, of weed seeds, nematodes, and various noxious organisms.
5. It must not have a high salinity level.
6. It should be capable of being sterilized with steam without harm.
7. There should be adequate cation exchange capacity to maintain nutrient availability.

In addition, the most outstanding characteristic for containerized seedling tree culture is that it be lightweight. Since sand and soil are excluded primarily because of weight, what have been termed "soil less" media are discussed.

Peat.—The most common component of CTS growing media, and the most highly recommended, is sphagnum peat. Peat consists of the remains of aquatic, marsh, bog, or swamp vegetation which has been preserved underwater in a partially decomposed state (Hartmann and Kester 1959). The composition of this material varies. The differences depend on the plants from which it originated, degree of decomposition, chemical content, and acidity. There are three basic types of peat: moss peat, sedge, and peat humus (Hartmann and Kester 1959).

Moss peat or "peat moss" is composed of sphagnum, hypnum, or other mosses. While hypnum moss is used in many ornamental container growing media and a few coniferous container media, sphagnum moss peat is most highly recommended for CTS media (Armson and Sadrieka 1974, Brix and van den Driessche 1974, and Hellum 1975).

Sphagnum moss is the dehydrated young residue or living portions of acid plants in the genus *Sphagnum*. This material, as opposed to sphagnum moss peat, is not decomposed to any degree. Sphagnum moss peat, not sphagnum moss is needed for CTS growing medium formulation. According to Hellum (1975):

"Peat sold commercially varies in character, causes problems in nurseries where seedlings are to be grown consistently to specific dimensions in a certain length of time. Only sphagnum peat, among organic materials, has the many desirable characteristics for a good CTS potting medium. There are many reasons—high water holding capacity, fibrosity, acidity (which means it is relatively free of fungi and bacteria), its breakdown makes nutrients available, and it has high cation exchange capacity compared to most mineral soils.

"Available commercial sphagnum peat varies by species composition, organic deposit which is mined, vendor, year of mining, and handling and use. Avoid peat composed of mosses other than *Sphagnur* because of desirable sphagnum water holding capac ties and fibril strength. *S. fuscum* is the best specie Peat should be from as acid minerotrophic fens a can be found, and peat from fens with pH above 6. should be avoided.

"Peat should not be exposed to air for more than few months before use, because this hastens hum fication (nitrogen release) and may cause top-heav seedlings. Therefore:

1. Only sphagnum peat should be used that has minimum of grass and other moss species.
2. Choose peat from fens where small leave species of *Sphagnum* are dominant; *S. fuscur* is best.
3. Look for peat that has been hydraulicall mined. It will be more consistent than surfac mined peat.
4. Avoid force dried commercial peat, whic generally gives less consistent results than bul mined *Sphagnum* peat that has not been forc dried."

Armson and Sadreika (1974) note, "Peat should b fibrous and free of woody fragments and mineral so inclusions. With peat moss it is usually necessary t put it through a hammermill; all peats have t undergo screening in order to produce a unifor homogeneous material for the containers. Physic condition of peat is critical in relation to the filling c containers. If the peat is too dry, it will not flo evenly and great difficulty may be experienced i wetting it. The result will be uneven levels in the cor tainers and large air spaces, both of which will resu in uneven seedling development. On the other han a peat which is too wet will also not fill or settle un formly into containers.

"The main chemical property of concern is that c pH; preferably the range should be 4.5 to 6.0. Oth properties, such as nitrogen, phosphorus, potassiu levels and also those of other nutrient elements are c less concern, because a program of fertilization necessary if satisfactory growth is to be maintaine Peats with excessively high levels of nutrients whic might be toxic should not be used. Table 9-2 giv results of analyses for a range of peats used container production in Ontario."

Vermiculite.—Hartmann and Kester (1950) expla that vermiculite "is a micaceous mineral whi expands markedly when heated. Extensive deposi are found in Montana and in North Carolina. Chen ically, it is a hydrated magnesium-aluminum-irc silicate. When expanded it is very light in weight (6 10 pounds per cubic foot) (100-140 kg/m^3) neutral reaction with good buffering properties, ar insoluble in water; it is able to absorb large quantiti of water—3-4 gallons per cubic foot (400-450 l/m^3

able 9-2.—Chemical analyses of unfertilized peats used in Ontario container stock production (all elements % o.d. weight) (Armson and Sadreika 1974).

Origin	pH	Cation exchange capacity meq/100 g	N[1]	P	K	Ca	Mg	Cu	Fe	Mn	Zn
hessalon	4.8	76	1.61	0.05	0.03	1.00	0.002	0.002	0.775	0.018	0.003
wastika	6.0	87	1.31	0.05	0.02	1.75	0.002	0.001	0.340	0.012	0.002
ort Frances	5.9	124	1.91	0.01	0.03	2.60	0.401	0.001	1.300	0.005	0.003
/hite River	5.8	78	0.81	0.03	0.03	0.14	0.003	0.002	0.330	0.008	0.002
learst	6.8	172	0.91	0.04	0.04	4.21	0.407	0.002	0.210	0.024	0.003
ochrane	4.8	99	1.11	0.17	0.20	2.02	0.311	0.481	0.330	0.102	0.014

[1] *N determined by micro-kjeldahl procedure, all other elements in solution after ashing of peat.*

/ermiculite has a relatively high cation exchange apacity and thus can hold nutrients in reserve and ater release them. It contains enough magnesium nd potassium to supply most plants. In the crude ermiculite ore, the particles consist of a great many ery thin, separate layers which have microscopic uantities of water trapped between them. When run hrough furnaces at temperatures near 2,000°F 1,100°C) the water turns to steam, popping the ayers apart, forming small porous, sponge-like ernels. Heating to this temperature gives complete erilization. Horticultural vermiculite is graded into our sizes: No. 1 has particles from 5 to 8 mm in iameter; No. 2, the regular horticultural grade, rom 2 to 3 mm; No. 3, from 1 to 2 mm; and No. 4, hich is most useful as a seed-germinating medium, rom 0.75 to 1 mm. Expanded vermiculite should not e pressed or compacted when wet, as this will estroy its desirable porous structure."

In most cases, vermiculite is an important gredient in growing medium mixtures for CTS roduction. There is much less agreement about the ze of vermiculite to be used. Indeed, there seems to e considerable confusion regarding the terminology urrounding the material. Some writers refer simply "vermiculite" with no further definition. A umber refer to "attic fill" vermiculite. Generally, is means a coarse grade of vermiculite equivalent to orticultural grade No. 1 to 1½. Some users simply fer to using "horticultural grade" vermiculite, hich usually means No. 2 (from 2 to 3 mm). Probly horticultural vermiculite grade No. 2 or 3 is the ost commonly used if readily available, but the ade of vermiculite used is not as important as how ell it works as a mix component. The purpose of corporating vermiculite or perlite in a growing edium with peat or ground bark is to keep the owing medium from settling and compacting to the int where good root aeration and water drainage is st.

Horticultural grade No. 1 is recommended for any ntainer of 10 cubic inches (160 cm³) or more, and o. 2 for smaller containers. Finer vermiculite will not function well as a bulking agent to prevent settling and should be used only for very short-term crops or ones that can tolerate poor aeration. Vermiculite bought as a "poultry litter" or "attic fill" insulation is usually cheaper than the same thing bought for horticultural use. Do not buy "block fill" that has been treated to make it water repellent.

Perlite.—Perlite is used in CTS growing media instead of vermiculite. It is also often used as a seed covering medium (section 16.33). Hartmann and Kester (1959) describe perlite as a "grey-white siliceous material of volcanic origin mined from lava flows. The crude ore is crushed and screened, then heated in furnaces to about 1,400° F (760° C), at which temperature the small amount of moisture in the particles changes to steam, expanding the particles to small, sponge-like kernels which are very light, weighing only 5 to 8 pounds per cubic foot (70-120 kg/m³). The high processing temperature gives a sterile product. A particle size of 1-3 mm in diameter is usually used in horticultural operations. Perlite will hold three to four times its weight in water. It is essentially neutral, with a pH of 6.0 to 8.0, but with no buffering capacity; unlike vermiculite, it has no cation exchange capacity and contains no mineral nutrients. It is most useful for increasing the aeration in a mixture."

The main advantage of perlite for use in CTS growing media is that it does not compress. However, it sometimes will make root plugs harder to extract, but this is important only in plug container types. Vermiculite is used much more often in CTS media than perlite.

Ground bark.—In some instances, ground bark has been used instead of sphagnum peat (Wood 1974). Some types of fresh bark contain materials toxic to plants (Hartmann and Kester 1959). When finely ground bark is used as a substitute for peat moss, supplemental nitrogen is usually needed to prevent the tree seedlings from becoming chlorotic (Barnett 1974) because the bark begins to break down and uses the nitrogen. Also, van den Driessche (1974) reports that a 1:1 mixture of Douglas-fir bark and vermiculite only has about 70% of the cation exchange capacity (CEC) (72 versus 103 milliequivalents per 100 g of dry weight) of a 1:1 mixture of sphagnum peat-vermiculite.

Unless there is an overwhelming reason to use ground bark, sphagnum peat is probably preferable. The reasons include higher CEC, better C:N balance, less likelihood of less organisms and toxic substances, and greater weight. However, there is work going on regarding the use of sawdust and wood residues (Montano et al. 1977 and Lumis 1976).

Other components are used in some cases, but peat, vermiculite, perlite, and ground bark are the major ones.

9.33 Media Mixes and Mechanics of Aeration and Drainage

There is considerable variation in the proportions of growing medium constituents from one successful CTS operation to another. The most commonly used mix is a 1:1 mix of shredded sphagnum peat and vermiculite. Other ratios are used, most commonly a 3:2 or 3:1 mixture of these same components. Owston (1972) indicates a 1:1 or 3:2 mixture is best for Pacific Northwest species. In Wisconsin, Phipps (1974) found that the medium components and their relative proportions significantly influenced seedling growth, with the largest red pine seedlings produced on a 1:1 peat-vermiculite medium.

After trying numerous mixtures, Tinus (1974b) settled on a 1:1 peat vermiculite mixture. In Louisiana, Barnett (1974) is also using a 1:1 peat vermiculite mix. Some nurseries have successfully used straight peat without any vermiculite or perlite (Routledge 1974).

To determine the best growing medium for a given situation one must consider the degree of aeration and drainage required when using a given container in a given greenhouse, growing certain species. In general:

1. There is some degree of latitude in formulating growing media that the trees will tolerate (Phipps 1974 and Owston 1972). Usually trees will perform best in a certain mix. This can be discovered through simple experimentation.
2. As more and more vermiculite or perlite is added to the peat, the aeration and drainage of the medium in the container increase. Too much vermiculite may allow the mix to fall out of the root egress hole and prevent the root plug from being cohesive upon removal from the container.
3. Larger and deeper containers require greater drainage, because water must percolate through a greater length of medium.
4. The higher the humidity maintained in th greenhouse, the better drained the mediur should be.
5. The less evenly the water is distributed in th CTS greenhouse, the better drained the mediur must be, because some containers must be ove watered in order to thoroughly soak others.
6. Some tree species require good root aeratior others will tolerate less aeration.
7. Drainage should not be so rapid as to nece sitate overly frequent watering.
8. Drainage should not be so slow as to waterlo the container and starve the roots for air.

The proper aeration and drainage can be measure as a percentage of macropore space in the growin medium. Hellum (1975) states that for a straight pe medium, about 25% macropore space is needed f good seedling root development. For peat-vermic lite mixes good macropore space can vary betwee 10% and 50% depending on the depth of the co tainer, with very deep containers being nearer 50% Nelson (1973) describes how to measure the macr pore space of the various media mixes in figure 9-11 through F.

If the trees grown in the medium do not perfor well and the grower suspects poor aeration ar drainage may be part of the problem, the proportio of components can be altered. The percentage macropore space, which is related to how trees gro can be found for the new mixture. By continue comparisons of the tree condition to the mediu mixture, the best macropore space percentage f that container, species, and greenhouse situation c be found over several crops of seedlings.

Symptoms of problems with the mix are:

1. Too coarse (too well drained, aerated): mediu falls out of root egress holes, root plug n cohesive, plug easily falls apart, very freque watering needed to keep the medium dam trees stunted.
2. Too fine (not well drained, aerated): mediu appears waterlogged, dries out slowly, fung diseases prevalent, infrequent irrigation nec sary, high EC reading on leachate, tre stunted, chlorotic, algal development growing medium surface prevalent, and th may be root rot.

9.34 Preparation of growing medium

Preparation of the growing medium for loadi into containers is relatively simple. Essentially, it the blending of the components to provide a medi of uniform texture and proper moisture content t is free of weed seeds and pathological organisms.

Mixing the growing medium components can done in a number of ways. Equipment is discussed

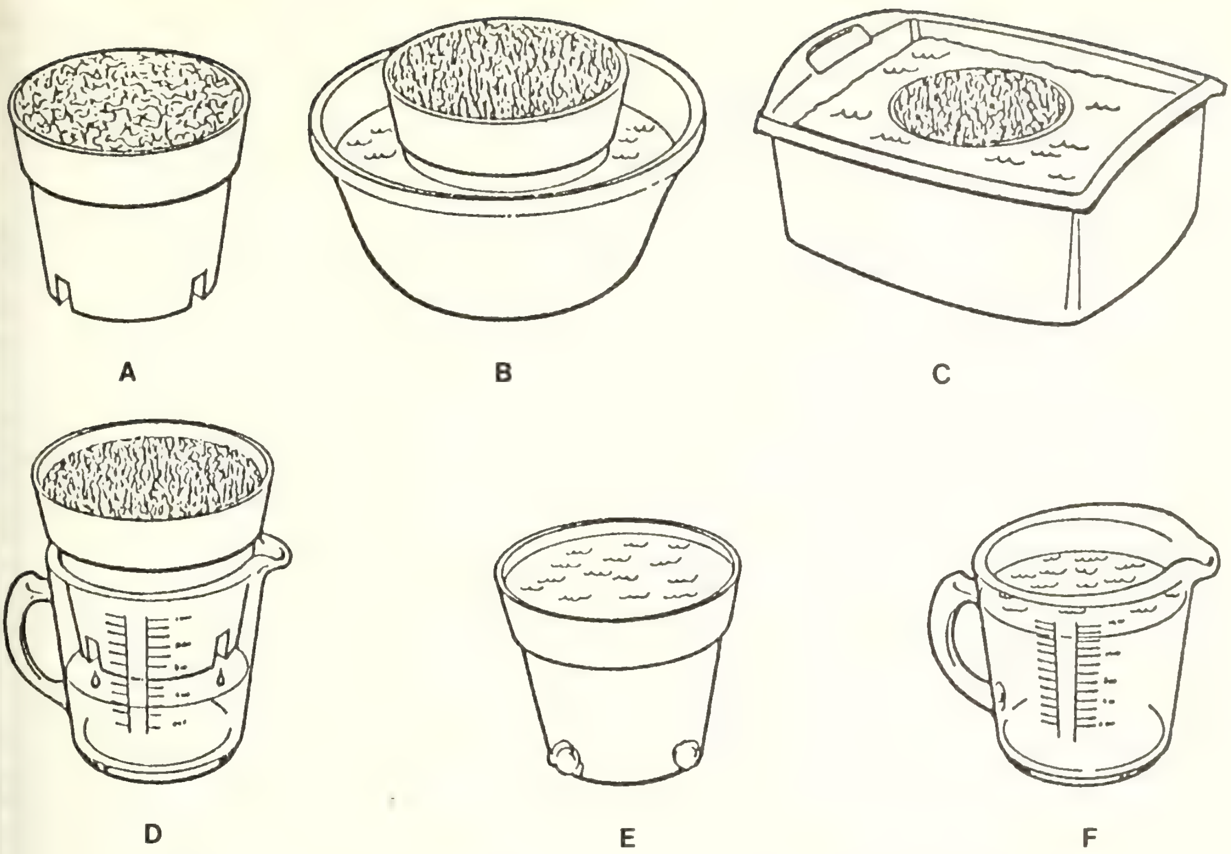

Figure 9-11.—(From Nelson 1973). Water drainage test for greenhouse soils. By means of this test, each grower can analyze his soils before planting and determine if the water drainage meets the standards of other soils he has used successfully. First make the test on a soil (either potting or bench soil) which drains well and is favorable for plant growth. Then make the test on the new soil mix before planting, compare results, and make the necessary adjustments to the soil mixture.

(A) Fill a plastic, 6-inch azalea pot with the soil mixture. Do not pack the soil in the pot, but from about a 3-inch height tap the pot on the counter top three times to settle the soil in the pot. The soil should be level with the top of the pot. (B) Subirrigate the pot of soil by placing it in a bowl with water about 3 inches above the pot bottom. Do not disturb for 24 hours. (C) transfer the pot of soil to a deeper pan and bring the water level in the pan to the top edge of the pot. Keep the pot in this pan until water is visible at the soil surface. (D) Transfer the pot of saturated soil to the measuring glass (a one-quart measuring glass should accommodate the plastic pot about as sketched). Let the pot drain for four hours, record the amount of water that drained, and mark the level of the soil in the pot after draining. Discard the soil and wash the pot. (E) Plug the pot holes with florist clay and fill the pot with water to the soil level after draining. (F) Measure and record the volume of water in the pot. The pot probably will contain more water than the one-quart measure will hold, but fill the measure to the quart level, dump, and measure the balance of the water in the pot.

To find the percentage of the pore volume that drained, as compared to the total volume of the soil, divide the amount of water that drained out of the pot by the total amount of water measured in the pot.

ction 7.2. Some other important operational points ould be noted.

The area and equipment to be used in the mixing ocess must be kept as clean as possible, not only e of refuse, but also free of weed seeds, fungi, and cteria. Equipment should be thoroughly washed th mild disinfectants before and after use. Good-n (1975) recommends a solution of commercial each (5% sodium hypochlorite) diluted 10:1 with water. Two percent formaldehyde, rubbing alcohol, boiling water, or live steam can also be used (Hartmann and Kester 1959). These methods can also be applied to flats, greenhouse floors, walls, and benches, as well as tools.

All growing media for CTS operations should have some water added to it during the mixing process. This is because peat or ground bark absorbs moisture very slowly. Addition of coarse organic materials, such as peat moss, to mixtures can cause a decrease in wettability. No good method for preventing nonwettability (hydrophobicity) is known. Use of commercial wetting agents may improve water penetration, but there are questions about their safety. Owston[2] reports decreased germination in pine resulting from the use of wetting agents. The water repellent quality of dry mixes containing peat is well known to CTS nurserymen who have filled containers with growing medium in a dry condition. In such cases, unlimited irrigation of the containers often will not wet the lower portions of the medium in the containers.

A slightly damp mix will not fall out of root egress holes while the container units are being handled, and will hold its shape after being compressed. The mix must not be wet or sticky, just damp. When it is properly moistened excess moisture can just be squeezed from the mix. Goodwin (1975) has provided some relative weights of dry and wet media shown in table 9-3.

Once moistened, the medium should not be allowed to dry out before or after the containers are filled and seeded. To help avoid this, seeded containers can be kept in cold storage for a period of time prior to loading the greenhouse.

9.35 Commercially Prepared Growing Media

A number of commercially prepared growing media, such as Jiffy-mix®, Micapeat®, Redi Earth®, and Pro-mix® have definite advantages for the CTS grower:

1. The grower does not have to mix his own except to moisten the product prior to filling the container. Large quantities may be ordered custom-mixed.
2. Most of the commercial mixes have nutrients added to them, which may provide needed nutrients to the crop.
3. The commercial mixes are usually claimed to be sterile. The nurseryman should not have to worry about sterilization.
4. They may be more evenly mixed than home-made mixes.

In other words, using commercially prepared mixes for CTS operations is very convenient. But there are disadvantages:

1. The grower gives up control of quality and type of component used in the mixture. This can vary with changes in company management and sources for components of the mix. A number of CTS growers have been surprised by plant responses to changes in growing medium. This is much less likely to happen with home-made mixtures.
2. Fertilizers or wetting agents added to the commercial mix may or may not be beneficial to tree seedling growth. Even if they are beneficial, their solubility in the container cannot be controlled by the nurseryman. In some cases, the fertilizers added are expressec only as N, P, and K, and the chemical source is not specified. Wetting agents are added to some of these mixtures and their possible phytotoxi effects have been mentioned earlier (sectior 9.34).
3. It may be necessary to alter the proportions o the components of the mix to achieve prope aeration and drainage. This is not possible wit commercially prepared growing media, onc purchased.

Because the source and preparation of the components of the growing medium is important, use o commercially prepared growing media for tree seedling culture is not recommended unless componen specification and quality can be guaranteed. Commercially prepared growing media are used by number of CTS growers, but a few growers hav tried and abandoned them for one reason or another

9.36 Addition of Fertilizer and Mycorrhizal Fun to Medium

The addition of fertilizers to the growing mediu before filling containers is discussed in section 13.2 For CTS operations it is not recommended. In CT culture, growth and final dimensions of the tre produced are controlled by adjusting fertiliz regimes and other environmental factors. Soluble fe tilizers, placed in the mix, will be leached-out rig away and do little good. Persistent fertilizers on complicate later cultural procedures.

Considerable work has been done on the additic of various species of mycorrhizal fungi to th growing medium (section 14.1). Many tree speci require fungal symbionts. Although some may n require them, they usually promote growth a make the seedlings less susceptible to root diseas

Table 9-3.—Weight (pounds) of 1 cubic foot of medium (Goodwin 1975).

Soil Mix	Dry	Moist	Saturated	Water gain
1 peat: 1 sand	54.00	64.5	84.0	30.0
1 peat: 1 vermiculite	6.25	27.8	46.8	40.5
3 peat: 1 vermiculite	6.90	28.5	47.5	40.6

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[2] *Personal communication with Dr. Peyton W. Owston, Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg., June 1978.*

esearch in progress is directed toward addition of ure cultures of specific fungi to the growing media arx and Barnett 1974, Zak 1977). CTS nurserymen ould expect some useful research results and, rhaps, commercially available cultures, by the end the decade. Some CTS producers are adding forest uff, assumed to contain mycorrhizal fungi, to owing media. In most cases, this procedure has re-lted in excellent mycorrhizal development. owever, there is an element of risk involved, cause the duff can contain inoculum of phyto-thological fungi, nematodes, insects, weed seeds, d other pests. Consequently, the practice of adding ff to growing media cannot be recommended thout reservations. The individual grower must ake this decision. To follow the practice in research vestigations is one thing; to expose millions of trees such risks in production operations is another.

37 Growing Medium Sterilization

The controlled environment of the greenhouse is nducive to the development of insects, disease thogens, and weeds, as well as crop plants. Every ailable means should be used to eliminate the urce of these problems before they get started. In rticultural potting mixtures, soil is almost always a mponent. Soil must be sterilized before use to oid serious disease problems. In CTS greenhouse erations, the growing medium is generally not rilized, because the medium components are often arly sterile to begin with (section 9.32). Some bark ntains compounds that are biotoxic. Also, the aracter of bark texture and the way it is usually ndled at mills, tends to allow weed seeds, spores, ., to be incorporated in it. Consequently, CTS owing media mixes containing peat, vermiculite, or rlite usually don't require sterilization, but ground rk components may need to be. In research, it is obably prudent always to sterilize the growing dium. In operational CTS projects, it is recom-nded only where there is demonstrated need.

There are several ways to sterilize soil or growing dia. The best and most widely used is heating the l with steam to about 180° F (82° C) for 30 nutes. This procedure will kill most harmful bac-ia, fungi, nematodes, insects, and weed seeds (fig. .2) (Hartmann and Kester 1959). Detailed steam rilization procedures are available in a number of rticultural texts such as Nelson (1973).

Chemicals are also useful for growing media rilization, if steam is not available. However, emical sterilization of mixes with vermiculite in m may be risky because the chemicals become und within the expanded vermiculite. This can ult in toxicity to seedlings even after prolonged aeration.[3] CTS nurserymen, therefore, are advised to use chemical sterilization with this possibility in mind. The more common chemical sterilants and how they are used in horticultural practice are provided in the following excerpt from Hartmann and Kester (1959):

"Chemical fumigation will kill organisms in the propagating mixes without disrupting their physical and chemical characteristics to the extent to which may occur with heat treatments. Ammonia production may increase following chemical fumigation, however, owing to the removal of organisms antag-

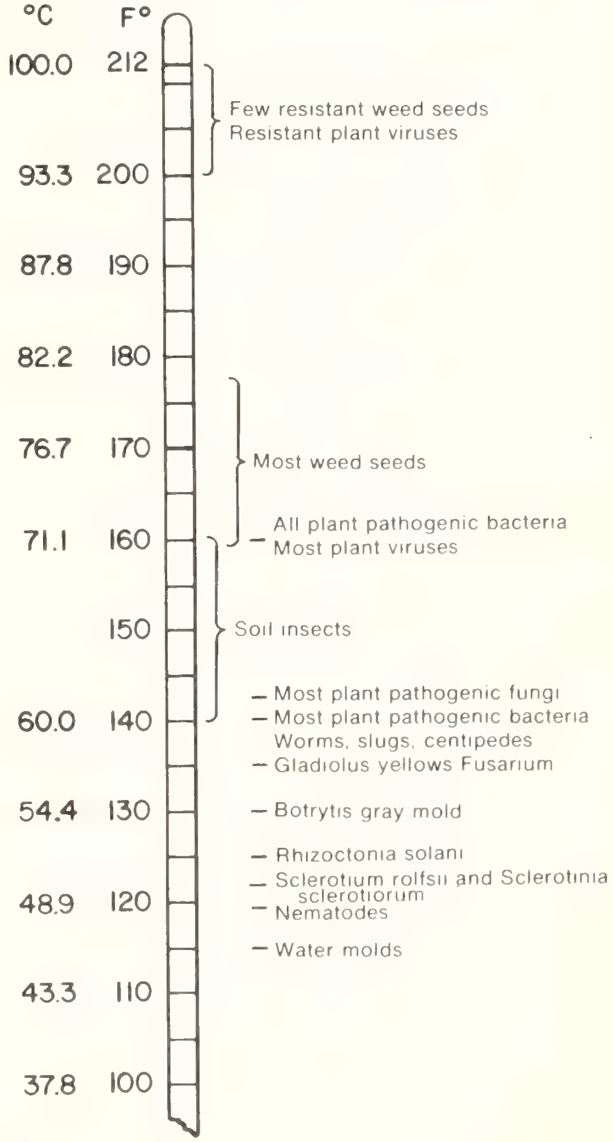

Figure 9-12.—Soil temperatures required to kill weed seeds, insects, and various plant pathogens. Temperatures given are for 30 minutes under moist conditions (Hartmann and Kester 1959).

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[3] *Personal communication with James P. Barnett, Southern For. Exp. Stn., Pineville, La., May 1978.*

onistic to the ammonifying bacteria. The mixes should be moist (between 40% and 80% of field capacity) and at temperatures of 65° to 75° F (18° to 24° C) for satisfactory results. After chemical fumigation, a waiting period for dissipation of the fumes of 2 days to 2 weeks, depending upon the material, is required for use.

"**Formaldehyde.**—This is a good fungicide with strong penetrating powers. It will kill some weed seeds, but is not reliable for killing nematodes or insects. Commercial formalin (40% strength) is mixed 1:50 with water and applied to the soil at the rate of 2 to 4 quarts per square foot (20-40 l/m^2) or 1 volume of 0.8% formaldehyde to 9 parts soil). The treated area should be covered immediately with an airtight material and left for 24 hours or more. Following this treatment, about 2 weeks should be allowed for drying and airing, but the soil should not be planted until all odor of formaldehyde has disappeared.

"For small-scale treatments, commercial formalin can be applied at a rate of 2½ tablespoons per bushel (1 ml/l) of a light soil mixture or 1 tablespoon (14 ml) per standard size flat. Dilute with five to six parts of water, apply to soil and mix thoroughly. Let stand 24 hours, plant seeds, and water thoroughly.

"**Chloropicrin (Tear Gas).**—This is a liquid ordinarily applied with an injector, which should put 2 to 4 ml into holes 3 to 6 inches (7-15 cm) deep, spaced 9 to 12 inches (23-30 cm) apart. It may also be applied at the rate of 175 ml/m^3 of soil. The gas should be confined by sprinkling the soil surface with water and then covering it with an airtight material, which is then left for 3 days. Seven to ten days is required for thorough aeration of the soil before it can be planted. Chloropicrin is effective against nematodes, insects, some weed seed, *Verticillium*, and most other resistant fungi. Chloropicrin fumes are very toxic to living plant tissue.

"Chloropicrin and methyl bromide are hazardous materials to use, especially in confined areas. They should be applied only by persons trained in their use and who will take the necessary precautions as stated in the instructions on the containers or in the accompanying literature.

"**Methyl bromide.**—This odorless material is very volatile and very toxic to humans. It should be used mixed with other materials and applied only by those trained in its use. Most nematodes, insects, weed seeds, and some fungi are killed by methyl bromide, but it will not kill *Verticillium*. It is often used by injecting the material at 1 to 4 pounds per 100 square feet (50-200 ml/m^2) from pressurized containers into an open vessel under a plastic cover placed over the soil to be treated. The cover is sealed around the edges with soil, and should be kept in place for 48 hours. Penetration is very good, and the sterilization effect will extend to a depth of 12 inches (30 cm). Fo treating bulk soil, methyl bromide at 4 pounds pe 100 cubic feet (6 kg/m^3) can be used.

"**Methyl bromide-chloropicrin mixtures.**—Proprietary materials are available containing bot methyl bromide and chloropicrin. Such combinations are more effective than either material alone i controlling weeds, insects, nematodes, and soil borne disease organisms. Aeration for 10 to 14 day is required following applications of methyl bromid chloropicrin mixtures.

"**Vapam® (sodium N-methyl dithiocarbamate d hydrate).**—This is a water-soluble soil fumiga which will kill weeds, germinating weed seeds, mo soil fungi, and, under the proper conditions, nem todes. It undergoes rapid decomposition to produce very penetrating gas. Vapam® is applied b sprinkling it on the soil surface, through irrigati systems, or with standard injection equipment. F seed-bed fumigation, 1 quart of the liquid form lation of Vapam® in 2 to 3 gallons water is use sprinkled uniformly over 100 square feet of area (1 diluted with about 10 parts water covers 9 m^2). Aft application, the Vapam® is sealed with addition water or with a roller. The soil can be planted t weeks after application. Although Vapam® has relatively low toxicity to man, care should be tak to avoid inhaling fumes or splashing the solution the skin."

SECTION 10.—OPTIMUM TEMPERATURES FOR GROWTH

10.1 Importance of Temperature

10.2 Optimum Temperatures

10.3 Thermostat Settings

SECTION 10.—OPTIMUM TEMPERATURES FOR GROWTH

10.1 Importance of Temperature

Temperature is the most important controllable reenhouse environmental factor. The greenhouse nclosure itself is the first step toward keeping both lay and night temperatures in the best growing ange. The most primitive control is to open a door r louvre or roll up the flexible side of a semiontrolled greenhouse, to release excess heat. At the ther extreme are banks of cooling pads, fans, and urnaces, with sophisticated multistage automatic lectronic controls.

A plant may be considered a complex of physical nd chemical reactions. Each individual reaction ccelerates by a factor of 2 to 3 for each 10° C rise in emperature up to the point where the enzymes that romote the reaction are damaged. Each reaction has different rate at any given temperature. However, ormal plant growth is the result of many coorinated reactions in balance with each other. The ptimum growth temperature is that point at which he whole growth process proceeds rapidly and yet emains in balance (Tinus 1977b).

Some growth processes, such as photosynthesis, ccur in the daytime only. Other processes are influnced by light, but to a lesser degree. As a result, ptimum day temperature is frequently not the same s optimum night temperature.

There is a great diversity among plants in their daptation to different sites and climatic regions. herefore, it is not surprising that there is a great ariation in optimum temperatures for growth mong, and even within, species (Tinus 1974b, 970).

Plant growth is not uniform. It can be divided into ages such as seed stratification, germination, venile growth, exponential growth, and dormancy. ifferent metabolic reactions and a different balance mong reactions are involved at the different rowth stages; therefore, it would be expected that ptimum temperatures might be different at different ages.

Growth can be measured in a variety of ways. The ost common are height, caliper, and dry weight. nce it is possible to grow more according to one parameter than another, optimum temperatures for one kind of growth are not necessarily the same as for another (Tinus 1977b).

The nurseryman must know where to set the thermostat, and how much deviation from the setpoint can be tolerated. However, to use this information intelligently, the nurseryman should know how it is obtained and what its limitations are. Optimum temperature regimes for tree species can be determined by experimental methods using growth chambers. Such information is provided in this manual. However, all species are not included, because all species have not been studied. Therefore, an explanation of the experimental procedures required to ascertain temperature optima is included for two reasons:

1. To show how existing data was derived.
2. To show how the experiments were accomplished so the methods can be duplicated for other tree species.

10.2 Optimum Temperatures

In a good experiment, all conditions are kept constant except the variables to be manipulated. Temperature experiments almost have to be done in growth chambers, because only there can temperature be held to close enough tolerances. However, the purpose is to extrapolate the results to greenhouse conditions, so, it is important that all conditions other than temperature match expected greenhouse conditions as closely as possible. Experiments conducted at the Rocky Mountain Forest and Range Experiment Station at Bottineau, N. Dak., have attempted to do this. The growth chamber atmosphere is enriched with CO_2. A combination of sodium and multivapor arc lights provide light intensities up to the equivalent of full sunlight. The container and pot medium are the ones used in the greenhouse, and the watering and fertilization are highly favorable, if not optimum. If possible, the pot mix is inoculated with mycorrhizal fungi. The trees are grown from seed to the size required for field outplanting.

In a typical experiment, single tree seed sources are used, whenever possible, in an attempt to reduce the amount of variability in seedling growth. Several sources are used which are selected to represent large differences in latitude, altitude, rainfall, or other factors which might result in differences in response of different seed sources to temperature. Generally, there are differences in growth rate among seed sources, but so far, the day and night temperatures at which optimum growth occurred have not been very different. This is fortunate, because it means that all seed sources of the same species can be grown together in the same greenhouse.

Whenever possible, containers of the type that will be used in the greenhouse are used for the growth chamber experiment, but sometimes this is not practical. Sixteen day and night temperature combinations are produced by resorting the seedlings among four growth chambers twice a day. Some containers such as Rootrainers®, will not tolerate that much handling. Probably the best container for experimental use is the Styroblock® which is not only able to withstand repeated handling, but can easily be cut down to any size needed to fit the desired number of treatments, sources, and replications, in the available chamber space.

The pot mix used is 1:1 peat-vermiculite of a coarseness appropriate for the size of container used. Sufficient seed is sown so that very few cavities are left empty. The extra seedlings are thinned out after the danger of damping off is over, and transplanting is avoided if possible.

Growth chambers are programmed for a 16-hour day and 8-hour night. This corresponds to summer daylength at northern latitudes. For experiments to provide growing data for winter crops or at low latitude a shorter day is better.

The seedlings receive 30,000 to 90,000 lux depending on species.[1] Light intensity selected is at, or slightly above, the saturation point as determined by a search of the literature. This is within the range attainable in the greenhouses and adjustable by shading, except for species such as lodgepole and ponderosa pine which saturate only at extremely high light intensities. A complicating factor is that saturation intensity is a function of temperature and CO_2 concentration, and these relations have not been adequately explored.

Chamber atmosphere is maintained at 1,200-1,500 ppm CO_2 during the 16-hour day. CO_2 added to the atmosphere can as much as double the growth rate (Tinus 1972, 1974c, 1976). However, whereas the high CO_2 is maintained throughout the day in the growth chambers, it can only be maintained when the vents are closed in the greenhouse. In cool or cloudy weather, this may be most of the day, but on bright summer days, the CO_2 may be elevated for only a few hours in the early morning and again briefly at dusk. Under these circumstances, it is har to tell how much good the high CO_2 is doing. Hig CO_2 should raise the optimum temperature f growth, which, in turn, should permit the vents remain closed longer, but detailed information this relation is lacking.

The 8-hour dark period is interrupted by 1 minu of incandescent light every 15 minutes at about 5 lux. This produces the equivalent of a 24-hour phot period which effectively prevents dormancy in t majority of species tested. However, since temper ture and photoperiod experiments have usually be done simultaneously on a given species, it generally not known in advance if that photoperi regime will be effective.

Rearranging the seedlings among chambers twic day is not only hard on containers but on t seedlings as well. It is difficult to avoid damagi them, and they are unavoidably subjected to n chanical stress that greenhouse grown trees do r experience. We do not believe this changes their sponse to temperature, but there is no evidence eit way.

Probably the best evidence that results of th growth chamber temperature experiments are vali that successful crops have been grown using optimum temperatures recommended. When con tions in the greenhouse have been very different fr those recommended, growth has generally b poor.

For some species, the recommendations are ba on work by other investigators who were trying explain something about the ecology or silvicult of that species. In many cases, their experime conditions were quite different from what t would be in a greenhouse nursery. This informat should, therefore, be used with caution, si changes in any of several factors can affect resp to temperature (Tinus 1976b).

In these experiments, the seedlings were raise the size desired for outplanting and then harve and measured. No intermediate measurements v taken. The temperatures cited as optimum, theref are assumed to be constant for the life of the seed through several stages of growth. It may well be there are different optimum temperatures for ferent growth stages. This is indicated by ex ments by other investigators which were termin at different ages (Callaham 1962, Larson 1967, T 1971).

Measurements taken were height, caliper, fresh and dry weight of shoots and roots. For measurement a two-way analysis of variance performed, with day and night temperature as two variables. The error mean square was use calculate the coefficient of variability. Mean v for each of the 16 temperature treatments were ulated for each seed source and measurement. These vere expressed as a percent of the largest value and lotted on graph paper with day temperature as the bscissa and night temperature as the ordinate. The 0%, 80%, 70%, etc. isolines were drawn by hand y linear interpolation in two dimensions. Judgment s to how best to smooth the curves was guided the ollowing principles:

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[1] *One foot candle equals 10.8 lux (or 1 lumen per m^2).*

1. Maximum leeway is one-fourth of the coefficient of variability.
2. Isolines tend to be parallel.
3. Isolines do not have sharp corners.

The coefficients of variability for height and aliper were usually about 3-6% and dry weight 6-2%, which is quite low. Since differences approximately double the coefficient of variability are significant at the 5% probability level, a significant diference on the height and caliper graphs would be bout three-fourths the distance between contour ines, and for dry weight about 1½ times contour line listance. This is only approximate, however, ecause the graphs are hand drawn. Nevertheless, it s a useful indication of how much confidence can be laced in the temperature information.

On the basis of height, caliper, and dry weight, raph recommendations for setpoint and allowable ange were formulated. Height, caliper, and dry veight graphs are superimposed. The area within the 0% line of height and caliper and within the 80% ine for dry weight is considered the optimum range. he 80% line is used for dry weight, because the oefficient of variability is usually greater. Sometimes the optimums for different growth parameters ccur at different day-night temperature cominations. Then, a choice must be made as to which s most important to optimize and how to do it with he least sacrifice of the others.

Then, economic criteria are applied. Stable night emperatures are easy to maintain, because there is o incoming heat load from the sun. However, utdoor night temperatures are almost always lower han optimum, so, heat is required in the greenhouse. Many species have surprisingly high nighttime ptimum temperatures. To maintain these would be xpensive, especially during cold weather. The trategy is to lower the night temperature from the ptimum to a temperature at which both the growth oss and cost of heating are acceptable.

Control of day temperature is complicated by incoming solar radiation. Whether the problem is to keep the temperature up or down depends on the season and the weather. The recommended setpoints in table 10-1 are based on summer conditions where daytime cooling is necessary. The allowable ranges tend to be on the high side, because when the cooling capacity of the system is exceeded, shading is usually the only alternative. Most shading systems require hand labor to put on and take off and are enough of a nuisance that it should be done as infrequently as possible.

The allowable range is the temperature region within which the greenhouse should operate 95% of the time. When temperatures are outside the allowable range for a short time, growth is lost, but usually no permanent damage is done. There are exceptions, however. Except for real extremes of temperature, the principal danger is that the seedlings will be thrown into dormancy and their growth delayed enough that the crop is not ready on schedule. Sometimes this can be as great a loss as if the crop were actually destroyed. However, a certain amount of temperature fluctuation is permissible and even desirable. Within the allowable range, a greenhouse is cheaper to operate, if the temperature is allowed to fluctuate a few degrees than if it is held to very close tolerances.

10.3 Thermostat Settings

The nurseryman will not go wrong using the figures listed in table 10-1 or table 10-2 (Fahrenheit). He may be able to refine them somewhat for his own operation to allow for crops grown in different seasons or experience gained with his species. To do so, use the modification procedures outlined in section 10.2 and the graphs in appendix 1. This will be an especially useful exercise, if the nurseryman intends to grow more than one species at a time. He can use the graph to decide which species are compatible and which should be grown separately. For those that appear compatible, he can pick the best compromise for setpoint and allowable range.

Note that thermostat settings are provided only for those tree species for which data exist. Much more work needs to be done to acquire data for other important tree species.

Table 10-1.—Recommended temperature settings (°C) for maximum growth of tree seedlings from end of germination to dry weight indicated when all other environmental conditions are optimized.

Species	Seed source	Max. dry wt. (*gm*)	Day set point	Temp. allowable range	Night set point	Temp. allowable range	Information confidence level[2]	Authority
Abies magnifica (A. Murr.)	North Coast, Calif., 1,800 m	1.7	17	16-19	5	4-10	B	Hellmers (1966a)
Celtis occidentalis L.	Bismarck, N. Dak.[1]	7.2	31	25-32	19	18-26	B	Tinus
Juglans nigra L.	Manhattan, Kans.[1]	18.4	28	26-30	22	19-28	A	Tinus
Juniperus scopulorum Sarg.	Denbigh, N. Dak.[1]	5.6	25	21-28	18	12-26	A	Tinus
Juniperus virginiana L.	Towner, N. Dak.[1]	11.9	24	21-26	21	19-26	A	Tinus
Larix sibirica Ledeb.	Denbigh, N. Dak.[1]	6.3	25	24-28	22	16-26	B	Tinus
Picea engelmannii (Parry)	Larimer Co., Colo., 3,140 m	8.3	19	17-23	23	22-24	B	Hellmers, et al. (1970)
Picea glauca (Moench) (Voss)	Central Alberta	0.37	22	21-25	19	16-20	A	Tinus
"	Fairbanks, Alaska	0.39	22	20-24	16	13-22	A	Tinus
"	Kenai, Alaska	0.43	22	20-25	19	16-26	A	Tinus
Picea pungens (Engelm.)	Ft. Collins, Colo.	9.4	20	18-25	22	19-26	A	Tinus
"	Indian Head, Sask.[1]	8.9	22	18-25	19	17-23	A	Tinus
Pinus contorta var.	Central Alberta	0.56	25	22-28	16	14-19	A	Tinus
latifolia Engelm.	Whitehorse, Yukon Territory	0.50	22	20-24	19	16-20	A	Tinus
Pinus palustris (Mill)	Mississippi		23	17-26	17	17-23		Bates (1976)
Pinus ponderosa var.	Ruidoso, N. Mex.	19.1	22	18-26	24	18-25	A	Tinus
scopulorum Engelm.	Safford, Ariz., 2,770 m	0.5	17	16-19	22	21-23	B	Callaham (1962)
"	Valentine, Nebr.	15.6	22	20-25	24	20-25	A	Tinus
"	Black Hills, S. Dak.	0.12	23	20-24	23	20-24	B	Larson (1967)
"	Moon, S. Dak., 1,890 m	0.5	23	20-27	22	21-23	B	Callaham (1962)
Pinus radiata D. Don	Cambria, Calif.	12.9	20	19-23	5 or 20	4-7;17-23	B	Hellmers and Rook (1973)
Pinus sylvestris var. *uralensis*	W. Ural Mtns., Russia	9.1	19	18-21	28	25-31	A	Tinus
Pinus sylvestris var. *balcanica*	Central Russia	7.1	19	18-22	25	22-31	A	Tinus
Pinus taeda L.	North Carolina		26	23-29	20	17-23		Bates (1976)
Pseudotsuga menziesii var. *menziesii* (Mirg.) Franco	Vancouver Island, B. C.	2.4	22	17-25	18	13-22	B	Brix (1971)
Quercus macrocarpa Michx.	Devils Lake, N. Dak.	7.2	31	26-32	19	17-26	A	Tinus
Sequoia sempervirens (D. Don) Endl.	Klamath, Calif.	29	19	18-20	16	15-17	B	Hellmers (1966b)
Tsuga heterophylla (Raf.) Sarg.	Vancouver Island, B. C.	1.4	18	17-20	18	13-20	B	Brix (1971), Owston and Kozlowski (1978)

[1] *Location from which seed was obtained, not the origin of native stand.*

[2] *See Section 1.2.*

Table 10-2.—Recommended temperature setting (°F) for maximum growth of tree seedlings from end of germination to dry weight indicated when all other environmental conditions are optimized.

Species	Seed source	Max. dry wt. (*gm*)	Day set point	Temp. allowable range	Night set point	Temp. allowable range	Information confidence level[2]	Authority
Abies magnifica (A. Murr.)	North Coast, Calif., 1,800 m	1.7	63	61-66	41	39-50	B	Hellmers (1966a)
Celtis occidentalis L.	Bismarck, N. Dak.[1]	7.2	88	77-90	66	64-78	B	Tinus
Juglans nigra L.	Manhattan, Kans.[1]	18.4	83	79-86	72	66-82	A	Tinus
Juniperus scopulorum Sarg.	Denbigh, N. Dak.[1]	5.6	77	70-82	65	54-79	A	Tinus
Juniperus virginiana L.	Towner, N. Dak.[1]	11.9	75	70-79	70	66-79	A	Tinus
Larix sibirica Ledeb.	Denbigh, N. Dak.[1]	6.3	77	75-82	72	61-79	B	Tinus
Picea engelmannii (Parry)	Larimer Co., Colo., 3,140 m	8.3	66	63-73	74	72-75	B	Hellmers, et al. (1970)
Picea glauca (Moench) Voss	Central Alberta	0.37	72	70-77	66	61-68	A	Tinus
"	Fairbanks, Alaska	0.39	72	68-75	61	55-72	A	Tinus
"	Kenai, Alaska	0.43	72	68-77	66	61-79	A	Tinus
Picea pungens (Engelm.)	Ft. Collins, Colo.	9.4	68	64-77	74	66-79	A	Tinus
"	Indian Head, Sask.[1]	8.9	72	64-77	66	63-73	A	Tinus
Pinus contorta var.	Central Alberta	0.56	77	72-82	61	57-66	A	Tinus
latifolia Engelm.	Whitehorse, Yukon Territory	0.50	72	68-75	66	61-68	A	Tinus
Pinus palustris (Mill.)	Mississippi		73	73-84	63	63-74		Bates (1976)
Pinus ponderosa var.	Ruidoso, N. Mex.	19.1	72	64-79	75	64-77	A	Tinus
scopulorum Engelm.	Safford, Ariz., 2,770 m	0.5	63	61-66	72	70-73	B	Callaham (1962)
"	Valentine, Nebr.	15.6	72	68-77	75	68-77	A	Tinus
"	Black Hills, S. Dak.	0.12	74	68-75	73	68-75	B	Larson (1967)
"	Moon, S. Dak., 1,890 m	0.5	74	68-81	72	70-73	B	Callaham (1962)
Pinus radiata D. Don	Cambria, Calif.	12.9	68	66-72	41 or 68	39-45; 63-73	B	Hellmers and Rook (1973)
Pinus sylvestris var. *uralensis*	W. Ural Mtns., Russia	9.1	66	64-70	83	77-88	A	Tinus
Pinus sylvestris var. *balcanica*	Central Russia	7.1	66	64-72	77	72-88	A	Tinus
Pinus taeda (L.)	North Carolina		79	73-84	68	63-73		Bates (1976)
Pseudotsuga menziesii var. *menziesii* (Mirb.) Franco	Vancouver Island, B.C.	2.4	72	63-77	65	55-72	B	Brix (1971)
Quercus macrocarpa Michx.	Devils Lake, N. Dak.	7.2	88	79-90	66	63-79	A	Tinus
Sequoia sempervirens (D. Don) Endl.	Klamath, Calif.	29	66	64-68	61	59-63	B	Hellmers (1966b)
Tsuga heterophylla (Raf.) Sarg.	Vancouver Island, B. C.	1.4	64	63-68	65	55-68	B	Brix (1971), Owston and Kozlowski (1978)

[1] *Location from which seed was obtained, not the origin of native stand.*

[2] *See Section 1.2.*

SECTION 11.—HUMIDITY CONTROL

11.1 Definition of Relative Humidity

11.2 Effect of Humidity on Seedlings

11.3 Determination of Optimum Humidities for CTS Growth

11.4 Control of Humidity

SECTION 11.—HUMIDITY CONTROL

11.1 Definition of Relative Humidity

Relative humidity is defined as the vapor pressure of water present in the air divided by the vapor pressure at saturation at the same temperature. Relative humidity is measured in preference to vapor pressure, because it is easy to make direct reading instruments which are almost independent of temperature.

11.2 Effect of Humidity on Seedlings

Relative humidity and temperature control the rate of evaporation from wet surfaces. Rate of evaporation is proportional to the vapor pressure deficit, which is equal to the saturation vapor pressure at a given temperature minus the vapor pressure present at the same temperature. Table 11-1 shows how vapor pressure deficit varies as a function of relative humidity and temperature. The higher the humidity, the less the transpiration.

Some workers believe that a small amount of transpiration is necessary to move mineral nutrients from the roots to the leaves. This is no problem, however, because in strong light, leaf temperature will be higher than air temperature, and, therefore, there will be a vapor pressure gradient from the leaf to the air even at 100% relative humidity.

It would seem that 100% relative humidity woul be optimum. This is not so, because fungi, mos liverworts, and other microorganisms thrive at ver high humidities, especially if there is free wat present. At humidities above 80-90% foliage diseas and damping off fungi become a major problem.

Plants must have their stomata open to absor CO_2 during photosynthesis. In the process, th transpire. As the leaves lose moisture, the intern water stress builds up. Elongation, which depends turgor pressure, slows down, and other internal pr cesses are adversely affected. At some point, t stomata close and net photosynthesis stops. Th series of events occurs regularly on sunny days most species, even when the seedlings are w watered. The roots cannot absorb water as fast as t leaves can lose it. When photosynthesis sto growth stops. For maximum growth, the stom must remain open as long as possible, and the less rate of evaporation, the longer in the day they v stay open.

During germination, the surface must be k moist so that the seed never dries out. Humidities 70-80% are desirable to avoid continual watering. soon as the radicle has penetrated well into the mix, the humidity should be reduced to 50-70% that the surface of the media and the foliage will fairly quickly after each watering. It is important there be adequate air circulation in the greenho otherwise the air will be stagnant within the cro of the seedlings, and the free moisture present a watering will keep the air in the vicinity of the fol saturated.

Table 11-1.—Water vapor pressure deficit (mm of mercury) as a function of relative humidity (%) and temperature.

Temperature		Relative humidity (%)										
°F	°C	0	10	20	30	40	50	60	70	80	90	1
104	40	55.3	49.7	44.2	38.7	33.2	27.6	22.1	16.6	11.1	5.5	
95	35	42.2	38.0	33.8	29.5	25.3	21.1	16.9	12.7	8.4	4.2	
86	30	31.8	28.6	25.4	22.3	19.1	15.9	12.7	9.5	6.4	3.2	
77	25	23.8	21.4	19.0	16.7	4.3	11.9	9.5	7.1	4.8	2.4	
68	20	17.5	15.7	14.0	12.2	10.5	8.7	7.0	5.2	3.5	1.7	
59	15	12.8	11.5	10.3	9.0	7.7	6.4	5.1	3.8	2.6	1.3	
50	10	9.2	8.3	7.4	6.4	5.5	4.6	3.7	2.8	1.8	0.9	
41	5	6.5	5.8	5.2	4.5	3.9	3.2	2.6	1.9	1.3	0.7	
32	0	4.6	4.1	3.7	3.2	2.8	2.3	1.8	1.4	0.9	0.5	

11.3 Determination of Optimum Humidities for CTS Growth

There have been few controlled experiments to etermine optimum humidity levels. One growth hamber experiment by Krizek et al. (1971) showed hat 40% relative humidity was severely limiting to eedling growth of ageratum, petunia, and marigold. aising the relative humidity to 65% resulted in triking increases in fresh weight, dry weight, leaf rea, and height. Increasing the humidity to 90% had o significant effect. The rest of what we know about e effects of humidity is not very precise and has een obtained by experience and general obervation. One reason is that precise humidity ontrol is difficult, because it changes so rapidly with mperature. Table 11-2 gives recommended setoints.

11.4 Control of Humidity

To increase greenhouse humidity:

1. Double layer the greenhouse cover. This is necessary during cold weather to prevent moisture from condensing on the cold outer wall. Without a double layer, it is likely to be impossible to maintain adequate humidity in cold weather regardless of the humidification system.
2. Add steam to greenhouse air. This is highly effective in a closed greenhouse, especially during winter.
3. Irrigate. This is highly effective but can result in overwatering or suboptimum leaf temperatures.
4. Use evaporative cooling. This is an important source of humidity during warm weather in arid climates.

To decrease humidity:

1. Ventilate. Make sure the air flow in and around the seedlings is adequate.
2. Ventilate and heat. Draw in outside air and heat it. Humidity will be lowered, even if the outside air is saturated.

Table 11-2.—Recommended greenhouse humidities.

	Relative humidity	
Growth stage	Optimum	Permissible range[1]
Germination	80%	60-90%
All other times	60%	50-80%

[1] *Humidity can remain at 100% during and after each watering, but should be lowered as soon as practical.*

SECTION 12.—EFFECTS OF LIGHT

12.1 Photosynthesis

12.11 Characteristics of Photosynthesis

12.12 Light Intensity and Saturation Levels

12.13 Artificial Light

12.2 Prevention of Dormancy

12.21 Relation of Photoperiod to Dormancy

12.22 Light Required for Dormancy Prevention

12.23 Suitable Light Sources and Installations

12.3 Light Requirements to Prevent Dormancy

12.31 Determination of Light Requirements

12.32 Tabulated Results by Species

SECTION 12.—EFFECTS OF LIGHT

All green plants require light which they use to control a variety of growth processes. The nurseryman is primarily concerned with two—energy for growth and metabolism (photosynthesis) and prevention of shoot dormancy.

12.1 Photosynthesis

12.11 Characteristics of Photosynthesis

Green plants take up water through their roots, take up carbon dioxide through their leaves, and they synthesize sugars in their leaves. The required energy comes from light. At low light intensities (0 to 1,000 lux), photosynthesis will be less than respiration, and there will be a net loss of carbon dioxide. As intensity is increased to 1,000-3,000 lux, depending on species, temperature, and other factors, photosynthesis will equal respiration, and there will be no net CO_2 exchange. This is the compensation point. Beyond this, photosynthesis increases rapidly and linearly with light intensity up to 10,000 lux and frequently beyond for many species. At higher light intensities, photosynthesis increases further, but not at the same rate. A point is reached at which a further increase in light intensity does not result in more photosynthesis; the tree is "light-saturated." There is no value in providing more light, in fact it is likely to be detrimental.

12.12 Light Intensity and Saturation Levels

Light saturation occurs at different light intensit for different species (table 12-1). It also occurs higher light intensity when temperatures are high when CO_2 concentration is greater, or in leaves th have been grown in full sunlight (sun leaves) opposed to those grown in shade (shade leaves).

Young seedlings have no shade leaves until af crown closure. They also receive considerable refl tion from the light colored grit or perlite covering pot mix. The effective light they receive is, therefo likely to be higher than a measurement of direct in lation would indicate. Most germinating seedlings best with light intensities around 30,000 lux. locations with high intensity sunlight, a 50% sha cloth over two layers of polyethylene will be ab right. For seedlings native to cloudy climates, sha cloth over the greenhouse (30-50%) may still be b even though the intensity is reduced to less t 10,000 lux. After the seedlings are well establish the light intensity should be raised to the saturat point by removing shade, if necessary. The c reason for not removing the shade would be if greenhouse could not hold acceptable daytime t peratures without it. Ideally, shading should be justed throughout the day and from one day to next to optimize light intensity. This is gener impractical, however, because most shading manually applied and removed, which is too s and laborious to do that often. It is important the shade be removable to match the light inter

Table 12-1.—Saturation light intensities for various species.

Species	Saturation light intensity (kilolux)	Authority
	Low	
Douglas-fir	30	Krueger and Ruth (1969)
Sitka spruce	30	″
western hemlock	30	″
white oak	15	Kramer and Decker (1944)
eastern red oak	35	″
dogwood	35	″
	Medium	
Engelmann spruce	50	Ronco (1970)
blue spruce	50-80	Tinus (1970)
red alder	50	Krueger and Ruth (1969)
	High	
lodgepole pine	120 +	Ronco (1970)
ponderosa pine	120 +	Tinus (1970)
loblolly pine	100 +	Kramer and Decker (1944)

vith the season of the year and the seedling stage of growth, however.

In sunny climates, during spring and summer, here is usually ample sunlight for seedling growth. n very cloudy climates, and during fall and winter, specially at high latitudes, there is frequently not nough sunlight for normal seedling growth. Certainly, the growth of a crop in a greenhouse will e slower during fall and winter than in spring and ummer. Obviously, unless production demands equire a winter crop, a summer crop can be raised more quickly and, often, more economically.

2.13 Artificial Light

It is possible to compensate for lack of sunlight by dding artificial light. The entire visible solar spectrum is utilized for photosynthesis, but all wavelengths are not equal in efficiency, and not all of hem are needed. This is fortunate, because few of he available light sources closely match the solar spectrum.

The most efficient wavelengths of light for photosynthesis are 600-700 nm in the red part of the visible spectrum. Infrared (700 nm and longer) is not used at ll but is absorbed and increases leaf temperature. Green and blue light (400-600 nm) are used with one-half to two-thirds the efficiency of red light. Ultraviolet (wavelengths shorter than 400 nm) is not useful and can be damaging. Therefore, the most efficient light sources for photosynthesis are ones which have maximum output in the red and none in he ultraviolet.

The minimum light intensity that is worth the effort is about 3-5 kilolux, and for good growth, the light intensity should be 7-12 kilolux. This assumes he artificial light is being used as a supplement to sunlight. If it is to be used as the sole source in what amounts to a growth chamber situation, then the intensity may need to be even higher, and it may be desirable to have other wavelengths in the spectrum needed for normal development, but not necessarily for photosynthesis.

For effective photosynthesis, the lights must be on for hours at a time at high light intensity. Such lights are expensive and impractical to install and operate unless electricity is very cheap. In this case, the choice is between building more greenhouse space or installing lights and getting added benefit from the existing space. See section 6.2 for lamp types best suited for photosynthetic lighting.

12.2 Prevention of Dormancy

12.21 Relation of Photoperiod to Dormancy

The other important function of light is control of bud dormancy by the effective length of day. Long daylight periods prevent dormancy in many woody perennials, while short days permit or induce dormancy. When seedlings cannot be reared to the desired size in a container nursery during the normal spring-fall growing season, must be reared over winter, or must be reared in a very short time, some control of photoperiod is necessary. In mild climates, no photoperiod control is needed to rear high quality seedlings of some species in one season. There are numerous examples of this in the semicontrolled environment CTS nurseries in the coastal Pacific Northwest. The determination as to whether lighting for dormancy prevention is needed depends on the nursery location, species to be grown, the time of year the crop is to be raised, and the amount of time available to grow the trees.

Photoperiod sensitivity in plants is caused by light-sensitive protein in the plant called "phytochrome" (Borthwick and Cathey 1962). Red light (660 nm) converts it to an active form which prevents dormancy. Far red light (735 nm) reverses the effect of red light and converts phytochrome to an inactive form. Phytochrome also reverts slowly to the inactive form in the dark. In addition to preventing dormancy, active phytochrome also retards stem elongation. Thus, to achieve maximum growth rate, enough active phytochrome must be present to prevent dormancy, but no more than necessary, because it will reduce height growth.

12.22 Light Required for Dormancy Prevention

There are several important differences between light required for photosynthesis and that required for dormancy prevention. For the latter, wave lengths shorter than 550 nm are of no value, and wavelengths between 700 and 770 nm reverse the effect of red light.

As red light intensity increases from zero, there is a threshold below which there is no growth response. Above the threshold, height growth increases rapidly and then tapers off at an upper limit above which there is no further response (fig. 12-1). For the majority of species, full response can be obtained with 400 lux (even less for some species (Arnott 1974, 1976, 1979)), which is two orders of magnitude less than what is required for photosynthesis.

The light required for photosynthesis is for power, which is why the light must be high intensity and continuous. In contrast, light for dormancy control acts as a trigger; it requires very little power and need not be continuous (Cathey and Campbell 1977). The lights can be on as little as 3% of the time, provided no dark period is longer than 30 minutes. Since the intensity and duration of light required for dormancy control is so small, it is not only economically feasible to provide this amount of light, but under most conditions, it is important to do so.

12.23 Suitable Light Sources and Installations

If the greenhouse is equipped with lights for photosynthesis, these lights will also prevent dormancy if operated to reduce the dark period to no more than a few hours. If lights are to be installed only for dormancy prevention, the lighting specifications will be quite different.

Planned light intensity should be 400 lux, minimum, expandable to 800 in case the species to be grown has a higher light requirement than most, unless it is known for sure that less than 400 lux is effective. The light intensity need not be uniform but must be above the minimum at all points. Second, the lights do not have to be on continuously. In fact, as long as the dark periods are kept shorter than 30 minutes, it is better if they are not. Equipment and lamps for dormancy preventing light systems are discussed in section 6.2 in some detail.

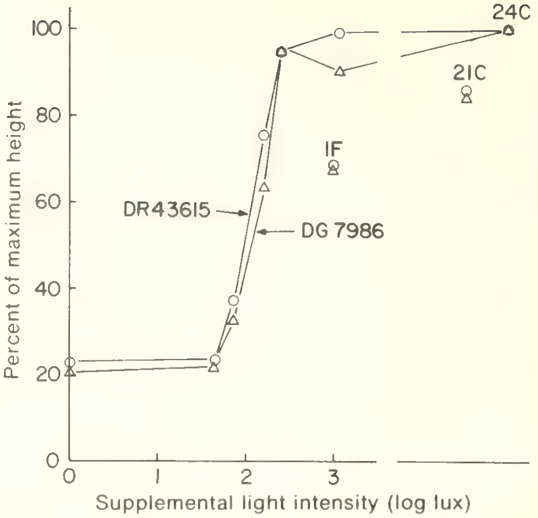

Figure 12-1.—Height growth response of white spruce to different intensity, duration, and quality of supplemental light. Triangles and circles represent two different seed sources as labelled. Unlabelled points are different intensities of incandescent light given 1 minute out of every 15 during the night. IF indicates intermittent fluorescent light on the same schedule; 21C was continuous incandescent light at 1,200 lux with a 3-hour dark period; 24C was the same as 21C with no dark period (Tinus 1976b).

12.3 Light Requirements to Prevent Dormancy

12.31 Determination of Light Requirements

At the USDA Forest Service Experiment Station in Bottineau, N. Dak., many species have been tested to determine the quantity and duration of light needed at night to maintain growth. A typical experiment is outlined here to acquaint the reader with methodology for acquiring lighting recommendations and so the method can be duplicated, if need be.

Seed is obtained from at least two seed sources widely separated in geographic origin and latitude so that any intraspecific differences would be likely to show up. These are planted in containers grouped into convenient-sized blocks. The choice of container is determined by the nursery needing the information. The planted containers are placed on a greenhouse bench which is divided into nine light-tight compartments at night, each of which is given a different light treatment. These are shown in table 12-2. The last four treatments were tried only in early experiments on ponderosa pine and blue spruce. Each compartment is attached to an air exhaust blower to minimize temperature differences between compartments at night. Each month, the positions of the various treatments on the bench are rerandomized to reduce the position effect caused by nonuniformity of daylight and temperature conditions in the greenhouse. The compartment opening and closing is synchronized with the natural day, so that it is closed and the photoperiod treatments operating whenever it is dark, up to a day length of 16 hours. In June, this means shortening the natural day somewhat.

After the seed coats are shed, the seedlings are watered as needed with a modified Hoagland's solution. The seedlings are grown under favorable conditions of temperature, sunlight, mineral nutrition, and watering. Conditions frequently are not optimum, however, either because they are not known at the time or because the conventional glass greenhouse in which the experiments are conducted is not able to maintain the desired conditions. When the average seedling in the best treatment reaches the desired size, the experiment is terminated. The seedlings are photographed, and height, caliper, and fresh and dry weight are measured.

Differences between treatments are tested by the Duncan multiple range test. Results are tabulated in percent of maximum height, caliper, and dry weight. When there are significant differences between seed sources within species, these are tabulated separately.

12.32 Tabulated Results by Species

Table 12-3 summarizes recommendations for long day treatment of each species tested.

Table 12-2.—Treatments used to determine light requirements to prevent dormancy.

Treatment code	Light source	Size (*watts*)	Light intensity (*lux*)	Duration
OW	None	0	0	0 (Dark control)
1W	Tungsten incandescent	12V, 1W	43	1 minute out of every 15
7W	"	7	75	"
15W	"	15	160	"
40W	"	40	270	"
100W	"	100	1,200	"
22F	Fluorescent	22	950	"
24H	Tungsten incandescent	100	1,200	Continuous all night
21H	"	100	1,200	Continuous except for a 3-hour dark period
1/30	"	100	1,200	1 minute out of 30
2/30	"	100	1,200	2 minutes out of 30
1B	"	100	1,200	1 hour light in middle of night
2B	"	100	1,200	2 hour light periods to break night into 3 equal parts

Table 12-3.—Response of various species to extended photoperiod and recommendations for use of extended photoperiod to prevent dormancy.

		Response[1]		Recommendation[2]			Information
Species	Seed source	Height	Dry weight	A	B	C	grade[3]
Celtis occidentalis	Bismarck, N. Dak.	1.2	1.8			X[4]	B
Quercus macrocarpa	Devils Lake, N. Dak.	1.2	1.2			X[5]	A
Juglans nigra	Manhattan, Kans.	1.1	1.1			X[6]	A
Juniperus scopulorum	Towner, N. Dak.	1.6	2.3		X		A
Juniperus virginiana	Towner, N. Dak.	1.9	2.4	X			A
Picea glauca	Central Alberta	4.5	>10	X			A
Picea pungens	Fort Collins, Colo.	1.4	7.7	X			A
Picea pungens	Indian Head, Sask.	1.4	7.7	X			A
Pinus contorta	Central Alberta	2.3	2.6	X			A
Pinus ponderosa	Ruidoso, N. Mex.	1.5	1.8	X			A
Pinus ponderosa	Valentine, Nebr.	3.1	3.6	X			A
Pinus ponderosa	Colorado Springs, Colo.	1.5	2.3	X			A
Tsugu heterophylla (Owston and Kozlowski 1978)	Oregon Coast	1.7	1.6	X			A

[1] *Response to long day equals average size in a given treatment divided by average size with no added light at night (control).*

[2] *Recommendation A—400 lux incandescent light minimum (86 watts/m^2) on 1 minute out of every 15 throughout the dark period. Interval is flexible provided lights are on 6% of the time and no dark period exceeds 30 minutes.*

Recommendation B—same as A, except 800 lux minimum.

Recommendation C—same as A, but response to long photoperiod is not strong. Other conditions are also required. See individual species footnotes.

[3] *Information grade: see section 1.2.*

[4] *Hackberry seems to maintain growth without long photoperiod, but use it for insurance anyway.*

[5] *Bur oak requires hot days and warm nights to maintain growth. Effect of photoperiod under these conditions is uncertain.*

[6] *Black walnut responds to long photoperiod only under high CO_2 (Tinus 1978b).*

SECTION 13.—MINERAL NUTRITION AND pH CONTROL

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SECTION 13.—MINERAL NUTRITION AND pH CONTROL

Information on nutrient needs of forest tree seedlings is skimpy.

13.1 Water Testing

All consideration of CTS fertilization begins with knowledge about the chemical composition of the water used for irrigation, regardless of fertilization method used. The nurseryman needs to know how to collect water samples for testing, what tests to ask for, and what the test results mean.

13.11 Tests Needed

The following should be included in a mineral analysis of irrigation water:

1. Total dissolved solids (mg/l or parts per million).
2. Electrical conductivity (μmhos).
3. Amount of all nutrient ions present (parts per million or mg/l) including: nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), sulphate (SO_4), iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), and chlorine (Cl).
4. Amount of other ions (parts per million or mg/l) affecting nutrient availability such as: sodium (Na) and carbonate (CO_3 or HCO_3).
5. Considering the possibility of heavy metal contamination of water supply as outlined in section 4.15, tests for the following ions may be advisable in rare instances: chromium (Cr), cadmium (Cd), arsenic (As), and mercury (Hg).
6. Finally, but very important, a titration table is needed to show the amount of a standard acid required to reduce the sample from its normal pH level to any pH down to 4.5. Specify that titration readings be taken at every 0.1 pH unit in developing the table (table 13-1).

13.12 Laboratory Selection

State water testing laboratories are normally equipped to make all of these tests, although they may not usually be asked to check for all of the ions specified or develop pH titration tables. The service is usually free, but often slow. If a private water testing laboratory is used, be sure it is reputable and willing and able to do all the tests. Ask how much water will be required to do the tests. Usually a quart is adequate and is easy to ship, but sometimes, more than a quart will be required.

Table 13-1.—Titration of Mount Sopris irrigation water with 0.02 N H_2SO_4. Sample size is 100 ml.

	Titrant used			Titrant used	
pH	ml	meq per l	pH	ml	meq per l
8.0	0.0	0.00	6.2	43.0	8.60
7.9	5.0	1.00	6.1	43.8	8.76
7.8	10.4	2.08	6.0	44.7	8.94
7.7	15.0	3.00	5.9	45.3	9.06
7.6	18.7	3.74	5.8	46.0	9.20
7.5	21.4	4.28	5.7	46.7	9.34
7.4	24.3	4.86	5.6	47.2	9.44
7.3	26.7	5.34	5.5	47.7	9.54
7.2	29.0	5.80	5.4	48.2	9.64
7.1	31.0	6.20	5.3	48.6	9.72
7.0	32.6	6.52	5.2	48.9	9.78
6.9	34.6	6.92	5.1	49.2	9.84
6.8	36.0	7.20	5.0	49.5	9.90
6.7	37.4	7.48	4.9	49.7	9.94
6.6	38.6	7.92	4.8	49.8	9.96
6.5	40.0	8.00	4.7	49.9	9.98
6.4	41.0	8.20	4.6	50.0	10.00
6.3	42.0	8.40	4.5	50.1	10.02

13.13 Water Sampling

The laboratory selected to do the work can recommend the type of container for shipping the sample. In general, metal containers or glass containers with metal lids should be avoided. Inert polyethylene containers, or glass containers with plastic lids are usually satisfactory. Samples should be collected as near to the location where the water will be used as possible. This is because the conduit between the source and the use point may have an effect on the chemistry of the water. The water should run long enough before the sample is taken to assure that the sample is representative of the production water, not water that has been in the pipeline for any length of time. Water stagnated in the pipe may differ in chemical composition from the norm. When collecting the sample, do not let the lip of the collection vessel contact the mouth of the faucet. The sample should be sealed and delivered to the laboratory promptly. When water test results are received, they are compared to the guidelines in this manual. These are in sections 13.3 (pH), 13.4 (electrical conductivity), and 13.61 (nutrient ion concentrations). Use of the results when contrasted with the guidelines is covered in the sections pertaining to formulation of nutrient solutions (sections 13.6, 13.7, and 13.8) depending on how the nutrient solutions are to be formulated. Frequency of water testing will depend on the nature of the water source. Surface water sources will be, generally, more variable chemically than well water. Annual and/or flow rate variations can be ascertained by frequent testing in the beginning. The changes may or may not be great enough to justify nutrient solution reformulation, but nutrient solution changes should be made whenever it appears warranted. Nutrient solution changes can also be keyed to changes in foliar nutrient content of trees. This is discussed in section 13.52.

A digression into fertilization method alternatives follows as a preface to detailed discussion of CTS mineral nutrition and pH control.

13.2 Fertilizer Alternatives

13.21 Mix Fertilizer with Growing Medium

Incorporating slow release fertilizers into the pot mix or adding granular fertilizer to the pot as a "top dressing" following potting is common in horticultural container nurseries. Topdressing fertilizer in CTS operations is impractical because of the container size. Adding such fertilizers to the potting mix has been tried to limited degree in CTS operations but has been abandoned in most instances. However, some work is proceeding on incorporation of very long-term release fertilizers designed to fertilize the tree 1, 2, or 3 years after outplanting.[1] The goal of this work is not to fertilize seedlings while they are being reared in the greenhouse. The authors do not recommend mixing fertilizer with growing medium in CTS operations for several reasons:

1. At some point in the growing cycle cessation of top growth is desired. This requires a change in fertilizer regimes. With fertilizer incorporated in the growing medium this is impossible. The program of nutrition the authors recommend begins with no nutrients during germination, a high nitrogen formulation during rapid growth, and high P and K during hardening. This program would be impossible to accomplish with solid fertilizers incorporated into the mix.

2. Growing trees in containers can take from a few months to a year, depending on the size of tree wanted and container used. It is very difficult to precisely match fertilizer pellet dissolution rates to the needs of tree seedlings for so long a time, particularly under greenhouse conditions.

3. Many of the slow dissolving fertilizers suitable for pot mix incorporation tend to raise the pH. Since many trees do best in acid or slightly acid conditions, this may not be desirable. Examples are incorporation of micronutrients in the form of slightly soluble glass frits, or ground dolomite ($CaCO_3MgCO_3$) to supply calcium and magnesium and to raise the pH of extremely acid peat.

13.22 Use Soluble Fertilizer Mixes

Most CTS nurseries use commercial soluble fertilizer. These powders or granules are dissolved in water and injected into the irrigation system of the greenhouse. In some small operations, the solution is sprayed over the trees by hand using equipment separate from the irrigation system. These fertilizers are formulated by a number of manufacturers. A variety of types are available, incorporating various concentrations and proportions of macronutrients and micronutrients.

As experience in growing different species of trees in different locations, containers, and potting mixes has accumulated, a great variety of fertilizer regimes have been developed using soluble fertilizer compounds. A nurseryman considering use of commercially prepared soluble formulations should find out what other CTS nurserymen are using and what their timing and other methods are. However, it is unwise to assume that what works in one situation necessarily works in another. This is because the fertilizer interacts with water composition of a specific site, the pot mix used, the species grown, and the growing conditions peculiar to each greenhouse. These variations can be compensated for by water testing, pH and electrical conductivity monitoring, and following nutrient solution formulation procedures outlined in section 13.7 of this manual.

Commercially formulated soluble chemical fertilizers are convenient to purchase and use. No chemical blending is required. The greenhouse crew merely selects the proper sack of mix, dissolves a measured amount of it in water, and injects it through the water system. But purchased mixes have drawbacks:

1. The manufacturer controls the precision of the formulation.
2. The user often does not know what chemical compounds are used to supply the nutrient ions, or if these compounds are changed from time to time. Both of these questions inject unknowns into the CTS cultural process that are hard to identify if something goes wrong with the trees.
3. The user is limited to the proportions of the nutrients available in mixes.
4. The salts used, especially phosphates, will affect the pH of the resulting solution. Therefore, it may be necessary to modify the pH by separate treatment, if the pH of the nutrient solution as applied to the trees is not what is desired.
5. Many water supplies already contain substantial amounts Ca, Mg, S, and, occasionally, some of the micronutrients. The nurseryman who formulates his own mix can take advantage of what is already in the water and avoid adding unnecessary salts.

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[1] *Personal communication with Phillip Hahn, Georgia-Pacific Corp., Eugene, Oreg., May 1978.*

In summary, soluble commercially prepared fertilizer compounds are used very successfully for fertilization in most CTS operations. The materials are convenient and easy to use, but some knowledge of the exact nature of fertilizer being applied is usually lost.

13.23 Formulate Nutrient Solution On Site

The third method of fertilizing tree seedlings is with homemade nutrient stock solutions, injected through the irrigation system. "Homemade," in this instance, means a fertilizer solution made by adding various amounts of technical grade chemical compounds to water according to a recipe developed for a particular water supply and crop. The advantages of this method of fertilization are:

1. The user knows exactly what chemical compounds are employed.
2. The user can tailor the fertilizer to his crop, pot mix, and water composition.
3. The components in the mix are entirely flexible.

Disadvantages are:

1. The user must develop the recipe himself or have someone do it for him. Some of the chemicals used may be hazardous, and may require more training to handle them safely.

2. The user must stock the variety of chemical compounds required and formulate the mix at the nursery. Each compound must be weighed into proper quantities for each bath of concentrate, and the opportunity for error is increased.

3. In many cases, the optimum nutrient concentrations are unknown, so, fine tuning the formulation to do an appreciably better job than a commercial mix is problematical.

13.24 Selection of Fertilization Method

The authors recommend that soluble salts at controlled concentrations be applied through the irrigation water. This method gives the best control of nutrition and the most flexibility, if a change is needed. The choice of commercial mix versus home brew is up to the nurseryman. Many fine seedlings are grown using commercial mixes, and it is quite possible that a custom formulation would not result in any improvement. However, if the nurseryman is willing to take the time and effort needed to make up his own, he will gain the confidence that he knows for sure what he has, and he can change it as needed to meet his own requirements or as specific knowledge of mineral nutrition improves.

13.3 Control of pH

13.31 Definition of pH

The pH indicates the relative alkalinity or acidity of a solution. A pH of 7 is neutral, while pH less than 7 are progressively more acid and those greater than 7 are progressively more alkaline. Soil pH is defined by the equation:

$$\text{Soil pH} = \log [\frac{1}{a_H+}]$$

in which the activity of H^+ in the soil suspension, a_H+, is expressed as gram-ions per liter (Jackson 1958). Normally, the effective concentration of hydrogen ions includes all sources, such as those arising by dissociation of soluble acids and those dissociated from soil particles. In practical terms, effective pH is defined as the electrical potential measured with a glass electrode applied to the soil system (Bates 1954). The electrical potential is measured with the potentiometer, or pH meter, described in section 6.56. The pH value or hydrogen ion activity of a soil is its most important chemical property as a medium for plant growth (Jackson 1958). The activity in the soils of the 12 or more different ions that enter into plant nutrition is highly dependent upon that of the hydrogen ion.

13.32 The Best pH for Tree Growth

Optimum growth of tree seedlings, and particularly conifer tree seedlings, occurs over a relatively narrow range of pH values (Wilde 1958, Brix and van den Driessche 1974), and control of pH is practical in CTS operations. The authors recommend target pH's of 5.0 to 6.0 for conifers and 6.0 to 7.0 for hardwood species (Wilde 1958 and Tinus 1977). These figures can be used where more specific information is lacking.

13.33 Dynamics of pH Control

Growing medium volume used in CTS operations is small when related to the number and size of plants grown. This means although a growing medium with considerable buffering capacity is used, pH of the medium and its soil solution can change rapidly. Large changes are undesirable for optimum plant growth. These changes can be due to differential removal of ions from the growing medium by the plants, by leaching, malfunction of a nutrient injector, and mistakes in fertilizer solution formulation. It is important, therefore, to start with a pot mix near the target pH for the trees to be grown and to attempt to maintain this pH closely in the growing medium as the crop develops.

The initial pH of growing media is discussed in section 9.32. Some Pacific Coast nurseries regulate pH by applying calcium nitrate or sodium hydroxide to raise the pH or ammonium sulphate or sulphuric acid to lower it (Brix and van den Driessche 1974). In other CTS operations, pH is neither monitored nor modified other than to make sure that the potting mix is initially acid. In most CTS operations, desired low pH levels are maintained by irrigating with acidified water, a procedure often used in horticultural cropping (Matkin and Petersen 1971). Considering the high value of CTS crops and the crucial nature of pH control to plant nutrition and disease control, nursery men should constantly monitor the pH of the growing medium, and make adjustment as needed. The pH is one environmental factor that is economically feasible to control.

13.34 Monitoring Methodology

The pH is conveniently measured at two places: the water applied and the leachate from the bottom of the container. To provide an adequate supply of water to the trees and prevent salt accumulation in the containers, container tree seedlings should be watered enough to insure that water flows through the container during each irrigation. The method for monitoring pH suggested in this manual consists of:

1. Measuring pH of the nutrient solution applied.
2. Measuring pH of the "leachate" (water that runs through the growing medium in the container).
3. Comparing the two readings to make inferences about the pH of the soil solution in the growing medium at time of reading and as a trend over time.

This method avoids the usual method of soil pH determination, where dry soil is mixed with water in some standard proportion, allowing the mixture to stand for about ½ hour, then, while the mixture is stirred, potentiometer electrodes are inserted, and the pH is measured on the soil suspension (Jackson 1958). The standard procedure would be very difficult to use in CTS operations because of the shape of the containers.

13.35 Sample Collection for pH Tests

The difficulty of catching leachate from containers varies with the type of container. It is essential the fluid that is caught is that which has passed through the medium of the container. Several container systems are designed so that irrigation water can reach the bottom of the bench, via cracks, dividers, holes, etc., without going through the container. This "bypass" water must not enter the sample being collected for pH measurement. In most cases, a minimum of 3 to 5 ml of leachate is required to take a pH reading; more is better. The sample size should be standardized. The pH of the first leachate coming from the container will be different from that coming later. This is not important as long as the same volume of fluid is caught at each collection.

13.36 Meaning of the pH Reading

The reading of the obtained leachate is not identical with the pH of the growing medium prior to irrigation. The reading will usually be between the pH of the nutrient solution applied and the pH of the growing medium prior to irrigation. The pH values recorded in consecutive irrigations will show trends. For example, if the desired pH for a conifer crop is 5.5 and the irrigation solution is adjusted to pH 5.3, the pH reading of the leachate may be around 5.5, and the actual pH of the rooting medium can be estimated to be 5.7. This means that the average pH of the growing medium between irrigations is probably around pH 5.5, fluctuating from near 5.3 immediately following irrigation to 5.7 just before irrigation. Uptake of nutrients, such as nitrate, and production of carbon dioxide by root respiration, which forms bicarbonate, usually elevates the pH between readings. The magnitude of such pH changes should be less than one full pH unit. The magnitude of the change can be reduced two ways: (1) irrigate more often, which means more frequent leaching of the growing medium, or (2) alter the chemical components of the nutrient solution, so that ion uptake by the plants releases less alkalinity.

A difference of 0.3-0.4 pH unit between leachate and irrigation solution pH would be considered normal. Large differences should prompt corrective action. First, examine the accuracy of the injection system. Check the irrigation solution pH, metering accuracy, and accuracy of nutrient or acid concentrate formulation. Second, see if increased irrigation frequency will solve the problem. As trees grow larger, they require more frequent irrigation. If actual added irrigation lags behind this need, pH and electrical conductivity readings of the leachate should rise. Last, if the spread between irrigation solution pH and leachate pH is still too wide, increase the acidity of the nutrient solution and perhaps reformulate it.

13.37 Relation of pH to Electrical Conductivity

Electrical conductivity (EC) readings (section 13.4) provide an estimate of the concentration of dissolved salts. EC and pH readings give the following information:

1. If a well-balanced nutrient stock solution is injected at an insufficient rate, then samples of

the irrigation solution (not the leachate) will be too dilute and exhibit abnormally high pH and abnormally low EC values.

2. If a well balanced nutrient stock solution is injected at too high a rate, then samples of the irrigation solution (not the leachate) will exhibit abnormally low pH and abnormally high EC values. This is a check on injector accuracy and concentrate formulation.
3. If the nutrient solution is out of balance, the EC value will be normal, but pH will be above or below the normal reading for the nutrient solution. This could occur in an instance where two solutions (where the concentrate components are not compatible in one concentrate solution) were being injected simultaneously through each of two injectors. Malfunction of the acid concentrate injector would cause the observed readings. The pH would be adjusted by altering either the concentrate or the injection rate for the acid concentrate solution. The other concentrate (containing salts primarily) would usually not require alteration.
4. If the pH fluctuates over time and the EC remains about right, there is reason to suspect corrosion in the acid injector is causing erratic behavior in its metering or a rise or decrease in carbonate content in the water supply (a seasonal phenomenon in some water sources).
5. From water test data and his own tests, the nurseryman will know the normal EC of his water. From tests of his irrigation solution, he will know the normal EC of the nutrient solution used for irrigation. If EC of the leachate is trending higher than normal, there is not enough leaching taking place during irrigation to remove the accumulated salts. Longer irrigations and more leaching are needed.

The pH and EC test results provide the primary data for checking and monitoring CTS acidification and fertilization procedures. These tests will give advance warning of incipient problems. Recording such data on a regular basis will usually show when corrective action is needed before any damage is done.

The foregoing assumes that all irrigation water is a dilute nutrient solution. At many nurseries, trees are fertilized only periodically. In these cases, a pH test is still of value to monitor performance of the injector and to check nutrient balance. It is possible to measure growing medium pH directly by taking a sample of it and measuring its pH in suspension, as previously described for soil analysis. EC readings of the leachate are also very valuable in these instances to prevent excess accumulation of salts in the containers.

13.38 Using a pH Meter

The actual procedures for using pH meters vary depending on type and design of instrument. Section 6.56 gives general recommended specifications for a pH meter. To use such a meter, the test solution is placed in a convenient vessel, the electrode is placed in the solution, and the pH is read directly on the dial. Many pH meters have a temperature compensation dial, since the instrument is temperature sensitive. Often, a warm-up time is needed to balance the instrument before use. This is not necessary with some newer instruments, however. Fragile glass electrodes usually are used. Even heavy-duty ones are subject to rapid deterioration if not properly cared for. Instructions for instrument care supplied with the meter should be followed exactly. Glass electrodes can fail because of rough use or chemical action; periodically the electrode should be tested (see instrument use book) to be sure it is functioning properly. Normally, the electrode of a pH meter is washed off with a strong stream of distilled water and, if recommended in instructions, dipped in the acid pH buffer solution provided. For storage after cleaning, the electrode is normally suspended in distilled water, and the system is protected from evaporation. Avoid letting the electrode dry out.

13.4 Control and Monitoring of Salt Concentration

The use of an electrical conductivity (EC) meter to monitor the EC of the irrigation solution and the leachate is essential in any container operation.

13.41 Definition of Electrical Conductivity

Electrical resistance is defined by the equation $E=IR$, where E is the electrical potential (in volts), I is the current (in amperes), and R is the resistance (in ohms). Electrical conductance, C, or conductivity, of a solution (in mhos) is the reciprocal of resistance (Bates 1954).

For convenience, conductance is read in millimhos (mhos^{-3}) or micromhos (μmhos). Actually, the unit read on a conductivity meter is usually micromhos per centimeter (μmhos/cm), or specific conductance.

13.42 Interpreting Electrical Conductivity Readings

The conductivity meter provides a quantitative estimate of the salt content of solutions extracted from soils (in this case leachate caught below the container) or of the irrigation water or nutrient solution. If the normal EC of the water supply and the diluted acidified nutrient solution EC are known, then changes in these figures can be recognized. Changes in EC indicate that the salt content of the water supply has changed, and a new chemical analysis of the water may be needed. In the case of a change in EC of the treated irrigation water, without a corresponding change in untreated water, an injector malfunction or an improperly formulated nutrient concentrate is probably the cause.

A rise in the normal EC of the leachate without a similar rise in the EC of the irrigation solution applied tells the nurseryman there is not enough leaching of the growing medium (i.e. not enough water being applied per irrigation cycle).

13.43 Magnitude of Electrical Conductivity Readings

Very pure irrigation water may be EC's as low as 100-200 μmhos, whereas very salty water may have EC's around 1,200-1,400 μmhos. Water carrying a complete nutrient solution and buffered for conifer growth, will range from 500-1,000 μmhos higher than the untreated water, normally in the 1,500-2,000 μmhos range.

High salt concentrations generally result in stunting, although the seedlings may also be chlorotic. Figure 13-1 shows the yield reduction to be expected from a range of salt concentrations for agronomic crops of various salt tolerances (Maas and Hoffman 1977). Most conifers are sensitive to moderately sensitive, and most hardwoods are moderately sensitive to moderately tolerant, although there are a few tolerant ones such as honeylocust and Russianolive (Dirr 1974, Bernstein et al. 1972).

If the leachate EC exceeds the nutrient solution EC by 1,000 μmhos or more, the nurseryman knows he is in real trouble. Normally, the two should be within 100-200 μmhos. If the EC of the leachate is 3,000 μmhos or more, the trees are probably dead or dying. Normally, total nutrient solutions should not be used if the EC of the irrigation formulation exceeds 2,200-2,400 μmhos. If this occurs, try a reformulation with different chemicals, because, if the containers dry only slightly at these high salt concentrations, the osmotic potential of the soil solution may become too high for growth. Lower EC levels will give the nurseryman a safety margin.

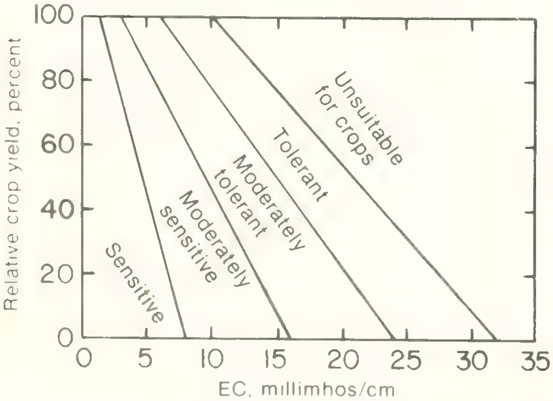

Figure 13.1—Relative crop yield as a function of soil salinity for plants of different salt tolerance (Maas and Hoffman 1977).

13.44 Conductivity Meter Operation, Records, and Accessories

The conductivity meter consists of the bridge and the cell (figure 6-38). The cell is ordinarily stored immersed in distilled water. In use, the cell is filled with test solution by immersing it into a container of the solution until the sensitive portion of the electrodes are completely covered. The bridge is balanced (as per specific unit operating instructions), and the meter is read. The EC and pH of the irrigation solution and the resultant leachate should be constantly monitored and systematically recorded.

Pressure gauges and flow meters can monitor water supply pressures and flow rates and check injector function, as discussed in section 6.4. These instruments are relatively inexpensive and provide an additional check on the function of the nutrient injection equipment by directly comparing amount of nutrient concentrate or acid injected to volume of irrigation solution applied. Because injectors wear out, corrode, or scale internally over time, such direct checks are valuable, and installing and monitoring of these simple devices is recommended.

In greenhouse operations, there is nearly always a work area with bench space for the pH meter, electrical conductivity meter, and associated equipment. This increases efficiency of the testing and record keeping, protects the instruments, and is certainly a worthwhile investment.

13.5 Seedling Mineral Nutrient Requirements

All green plants require 15 elements to thrive and develop normally. Each element has a specific function to perform (Kramer and Kozlowski 1960). Carbon, hydrogen, and oxygen make up most of the weight of the plant and are obtained from CO_2 and H_2O. All the other elements are taken up from solution or from the exchange complex in the pot mix. Nitrogen and sulfur are important constituents of proteins. Phosphorus is found in the genetic material of the cell and is important to energy transfer. Calcium pectate is the glue that holds cells together. Magnesium is a constituent of chlorophyll, and iron is a constituent of precursors of chlorophyll. Potassium makes the stomata operate and helps maintain ionic balance. Boron is involved in sugar transport. Zinc, copper, molybdenum, and chlorine activate enzymes.

13.51 Nutrient Deficiency Symptoms

When enough of the essential elements are not present, the plant cannot grow normally. Usually specific, recognizable nutrient deficiency symptoms develop. Although there is much variation in the appearance of the symptoms from one species to another and depending on their severity, the following descriptions taken from Behan (1968), Armson and Sadreika (1974), Hacskaylo and Struthers (1959), and Ingestad (1962), will be useful.

Nitrogen deficiency.—Seedlings are stunted. Older leaves fade and die; younger leaves are pale green to bright yellow. The transition from green to yellow portions of the leaf is abrupt, and there is no extension of chlorosis down the midvein into green areas. Chlorosis extends from the leaf tip toward the base. There may be purple or red spotting of the leaves, especially near the tips. Roots are black and necrotic.

Phosphorus deficiency.—Seedlings are stunted, but leaf size may or may not be reduced. Leaves are dark green turning to purple at needle tips or interveinal areas. Purple areas become brown and die. Appearance of broadleafed species is often varigated. Youngest needle tips of spruce and pine may be gold in color. Roots are sparse and purple to black.

Potassium deficiency.—Stems are short and stout. Youngest leaf tips and interveinal areas turn pale green to light yellow and fade to tan or grey. Transition in color from one part of the leaf to another is diffuse, not abrupt. In the field, uppermost exposed foliage on the largest seedlings is likely to be damaged the worst. Leaves at the tips of lower branches will be most damaged in the greenhouse. Roots are long and threadlike.

Calcium deficiency.—Youngest leaves are stunted, and their tips and interveinal areas may be yellow and faded. Leaf margins are pale yellow and buckled. Terminal and subterminal buds die or fail to elongate. Shoots are deformed and twisted; branching intensifies, resembling insect damage. Roots are black, and tips are dying.

Magnesium deficiency.—Leaf tips are bright yellow to orange, with the color progressing from tip to base along the entire length. Midvein chlorosis extends well into green interveinal tissue at leaf base; transition is diffuse. Cotyledons and lower primary needles of pine remain green.

Sulfur deficiency.—Stems are short and slender, with pale yellowish-green foliage. Leaves are abundant but small. Yellowing is even across veins and interveinal areas. Youngest leaves are most affected; older ones are less so.

Iron deficiency.—Symptoms appear first on the terminal leaves; older foliage is unaffected. New leaves turn pale yellow to almost white in interveinal areas or at needle fascicle bases. Roots are few but long.

Boron deficiency.—Terminal is stunted and forms a rosette. All else appears normal, although some foliage may exhibit interveinal chlorosis.

Deficiencies of Mn, Cu, Zn, Mo, or Cl also cause recognizable symptoms, but they are hard to characterize in a general way. Table 13-2 lists sources of information about deficiency symptoms with colored pictures and descriptions for individual species. Table 13-3 lists additional sources of information with emphasis on micronutrients.

Although specific deficiency symptoms attributable to certain elemental deficiencies have been discussed, it must be kept in mind that deficiency symptoms may be linked to pH levels, which are known to have strong effects on ion availability to plants. Also, high salt concentrations will cause symptoms that are similar to some nutrient deficiencies. The point is that CTS nutrition must be balanced to include proper elemental nutrition, at appropriate pH and electrical conductivity levels, to permit optimum CTS growth and development. All aspects of plant nutrition are interactive.

13.52 Foliar Analysis

When nutrient deficiency symptoms appear, a great deal of damage has already been done. It is best if a developing problem can be diagnosed at a much earlier stage. This can be done by foliar analysis. For each element there is a range of concentration in the leaf which is characteristic of optimum growth. Concentrations in excess of this amount may be toxic, but the margin between optimum and toxic will vary with the particular element. Below optimum nutrient concentrations will result in various degrees of growth retardation, and these will be detected by foliar analysis before the deficiency becomes so acute that specific symptoms are visible and irreversible damage done.

Foliar analysis needs to be calibrated. The levels of deficiency, optimum, and toxicity vary with species and with the growth stage of seedling (van den Driessche 1974). Foliage samples of large, field grown trees are generally taken in the late summer, because there is less variability in nutrient concentration than at other times of the growing season (Smith 1967) (table 13-4). In the greenhouse nursery, this corresponds to the first stage of hardening. However, the nurseryman may need to know the nutrient status of

Table 13-2.—Published color pictures showing symptoms of nutrient deficiencies in forest trees.

Species	Nutrient	Authority
Abies pectinata	N	Hausser (1958)
Chamaecyparis obtusa	P, Mg, Fe, Mn	Tsutsumi (1962)
Cryptomeria japonica	P, K, Ca, Mg, Fe	Tsutsumi (1962)
Juglans nigra	N, P, K, Ca, Mg, S, Fe, Mn, B, Cu, Zn, Mo	Hacskaylo and Struthers (1959)
Larix occidentalis	N, P, K, Ca, Mg	Behan (1968)
Liquidambar styracifula	N, P, K, Ca, Mg, S, Fe, Mn, B, Cu, Zn, Mo	Hacskaylo and Struthers (1959)
Picea abies	N, P, K, Mn	C. O. Tamm and Ingestad (1955)
	N, P, K, Cu	van Goor (1963)
	K, Mg	Ingestad (1960a)
	K	Bjorkman (1953), Themlitz (1958a)
Picea glauca	N, P, K	Armson and Sadreika (1974)
	N, P, K, Mg	Swan (1960)
	K	Heiberg et al. (1954), White and Leaf (1957)
Picea mariana	N, P, K, Mg	Swan (1960)
Pinus banksiana	N, P, K, Mg	Swan (1960)
	P	Armson and Sadreika (1974)
Pinus densiflora	P, K, Mg, Fe	Tsutsumi (1962)
Pinus radiata	N, P, K, Ca, Mg	Purnell (1958)
Pinus resinosa	Fe	Armson and Sadreika (1974)
Pinus strobus	Mg	Heiberg et al. (1954), White and Leaf (1957)
Pinus sylvestris	P, Mg	Moller (1904)
	N, P, K, Mg	van Goor (1963)
	K, Mg	Themlitz (1958a, b)
	Mg	Bruning (1959)
	N, P, K, Ca, Mg, S, Fe	Hacskaylo and Struthers (1959)
Populus deltoides	N, P, K, Ca, Mg, S, Fe, Mn, B, Cu, Zn, Mo	Hacskaylo and Struthers (1959)
Pseudotsuga taxifolia	N, P, K, Cu	van Goor (1963)
Robinia pseudoacacia	K, Mg	Bruning (1959)
	N, P, K, Ca, Mg, S, Fe, Mn, B, Cu, Zn, Mo	Hacskaylo and Struthers (1959)
Tsuga heterophylla	N, P, K, Mg	Swan (1960)

his seedlings at other times of the growing cycle as well. Table 13-5 lists average concentrations of elements found in healthy foliage of 30 woody species (Smith 1967, Powers 1976). Table 13-6 lists sources of information on individual species of nutrient content representing sufficient and deficient amounts and information on optimum nutrient solutions. They should be used only as rough guides until the nurseryman has established his own base line for nutrient content in seedlings growing well versus those that are not. As mentioned in section 13.13 (water sampling), changes in nutrient solution formulation can be attuned to foliar nutrient levels as well as changes in water source chemistry. This requires a highly evolved knowledge of the foliar nutrient content of the species being grown. Hahn reports he is utilizing foliar analysis to define nutrient solutions on a week-to-week basis.[1]

For additional information on mineral nutrition and the use of foliar analysis see Tamm (1964), Lavender (1970), Bates (1970), Commonwealth Bureau of Soils (1969).

13.6 How to Formulate Nutrient Solutions

The recommended method for calculating nutrient concentrate solutions is as follows:

1. Set the target nutrient concentrations and pH, as discussed in sections 13.32 and 13.61.
2. Determine from the water titration table how much acid must be added to meet the target pH.
3. Calculate how much of various chemical compounds must be put into a nutrient concentrate solution to supply the plants with the target quantities of nutrients. The solution must also correct the water pH to the target pH.
4. Decide how the compounds must be mixed and injected into the water system, and how much of the compounds should be kept in a working supply.

The process is more complex than these four steps indicate. To accomplish this requires a knowledge of chemistry and plant physiology beyond that normally expected of forest tree nurserymen. The fol-

Species	Element	Field	Laboratory	Deficiency	Toxicity	Growth reduction	Analysis of: Soil	Plant	Method	Authority
Agathis australis	Fe		x	x	x	x		x	Solution culture	Peterson (1962)
''	B		x	x	x	x			''	''
''	Mn		x	x	x	x		x	''	''
''	Zn		x	x	x	x		x	''	''
''	Cu		x		x	x		x	''	''
''	Mo		x	x	x	x		x	''	''
Betula verrucosa	Fe		x	x		x		x	''	Ingestad (1957)
''	B		x	x	x	x		x	''	Ingestad and Jacobson (1962
''	Mn		x	x				x	''	''
''	Mn	x		x		x		x	Foliar spray	Ingestad (1958)
Carya illinoensis	Mg	x		x			x	x	Fertilizers, foliar spray	Worley et al. (1975)
Eucalyptus spp.	B	x		x		x		x	''	Savory (1962)
Fagus sylvatica	Fe	x		x		x	x	x	Foliar spray, stem injection	Olsen (1943)
Juglans regia	Mn	x		x						Braucher and Southwick (194
Larix decidua, Picea abies	Cu		x	x		x			Soil culture	Rademacher (1940)
Larix laricina	All	x							—	Tilton (1977)
Liquidambar styraciflua	N,P,K	x				x			Fertilizers	Blackmon (1974)
Liriodendron tulipifera	N,P,K	x				x			''	''
18 Minnesota tree spp.	All	x						x	—	Henry (1973)
Picea abies	Fe		x	x		x		x	Solution culture	Ingestad (1959)
''	Mn	x		x		x		x	Foliar spray, stem injection	Ingestad (1958)
''	Mn	x				x		x	—	Madgwick (1967)
Picea glauca	N,P		x			x			Solution culture	Etter (1971)
''	Fe,Mn	x				x		x	Fertilizers	Iyer and Wilde (1973)
Picea mariana	Fe,Mn	x	x	x	x			x	Solution culture	Morrison and Armson (1968)
Picea rubra	All	x						x	—	Safford and Young (1968)
Picea sitchensis	Cu	x		x		x		x	Fertilizers, foliar spray	Benzian and Warren (1956)
Pinus banksiana	Ca,Mg	x		x		x	x	x	Fertilizers	Sadreika (1969)
''	Mn,Fe	x	x	x	x			x	Solution culture	Morrison and Armson (1968)
Pinus contorta	N,P		x			x			''	Etter (1971)
Pinus elliottii	N,P,K	x				x			Fertilizers	Shoulders (1974)
Pinus ponderosa	N,P,K		x			x			Pot test	Vlamis et al. (1957)
Pinus radiata	N,P,K							x	Fertilizers	Burdon (1976)
''	Ca,Mg	x				x				
Pinus radiata	B		x	x		x			Solution culture	Smith (1943)
''	Mn		x	x		x			''	''
''	Zn	x		x					Foliar spray	Knight (1976)
''	Zn		x	x		x			Solution culture	Smith (1943)
''	Cu		x	x		x			''	''
''	Mo		x	x					''	''
Pinus radiata, P. patula	B	x		x		x		x	Fertilizers, foliar spray	Vail et al. (1961)
Pinus radiata, P. pinaster	B	x		x		x		x	''	Will et al. (1963)
''	Zn	x		x		x		x	Foliar spray, stem treatments	Stoate (1950)
Pinus radiata, P. taeda	B		x	x	x	x			Solution culture	Ludbrook (1940, 1942)
Pinus resinosa	Fe,Mn							x	Fertilizer	Iver and Wilde (1973)
	Zn,Cu	x				x			Foliar spray	Korstian et al. (1921)
Pinus spp.	Fe	x		x		x		x	Solution culture	Ingestad (1960b)
Pinus sylvestris	Fe		x	x		x			Soil culture	Rademacher (1940)
''	Cu		x	x		x			Fertilizers	Schmidtling (1975)

Table 13-3.—Continued.

Species	Element	Field	Laboratory	Deficiency	Toxicity	Growth reduction	Analysis of: Soil	Analysis of: Plant	Method	Authority
Pinus taeda	N,P	x			x		x	x	"	Wells and Crutchfield (1969)
"	P	x				x			"	Shoulders (1974)
"	N,P,K	x				x			Solution culture	Lyle (1969)
"	All		x	x		x			Sand culture	Wilson (1953)
Pinus taeda, P. echinata	Zn		x	x		x			Fertilizers	Blackmon (1974)
Platanus occidentalis	N,P,K	x				x			"	"
Populus deltoides	N,P,K	x				x		x	Fertilizers, foliar spray	Benzian and Warren (1957)
Populus robusta	Cu			x		x			Stem injection	Starr (1940)
Populus spp.	Fe	x		x			x	x	Fertilizers	van den Driessche (1969b)
Pseudotsuga menziesii	N,P,K, Mg	x				x			"	van Goor (1963)
"	Cu	x		x					Foliar spray	Korstian et al. (1921)
Pseudotsuga taxifolia	Fe	x		x		x			Stem injection	Pirone (1940)
Quercus palustris	Fe	x		x					Fertilizers, leaf treatment	Hacskaylo and Struthers (1959)
Quercus palustris	Fe	x		x					Fertilizers	Blackmon (1974)
Quercus spp.	N,P,K	x				x				
"	N,P,K, Ca,Mg, Fe,Mn	x						x	—	Auchmoody (1972)
Thuja plicata	Fe		x	x		x		x	Solution and sand culture	Walker et al. (1955)
"	B		x	x		x		x	"	"
Tsuga canadensis	K,Ca		x	x		x			Solution culture	Olson et al. (1959)

Table 13-4.—Average monthly foliar mineral element content in percent of dry weight for 14 deciduous woody plants (Smith 1967).

Month	N	P	K	Ca
May	4.25	0.61	1.61	0.95
June	2.63	0.31	1.22	1.26
July	2.30	0.26	1.25	1.32
August	2.16	0.32	1.46	2.05
September	2.22	0.28	1.09	2.16
October	2.14	0.27	1.14	2.20

lowing sections provide a "cookbook" procedure for developing a tailored nutrient solution with minimal technical complication.

13.61 Desirable Concentrations of Nutrient Elements

This has been studied by quite a number of workers, but the results vary in their usefulness to nurserymen. In many experiments, the best treatment was at one of the scale of values tested. So, it cannot be said that the best treatment found is optimum. The concentration of one element frequently affects the optimum concentration of another. So, attempts to optimize concentrations of all of them become involved in very large factorial experiments. Few really complete optimizations have been attempted. Another complication is the variation between, and even within, species. Table 13-7 lists concentrations of nutrient ions found to be favorable and, in some cases optimum, according to species. Fortunately, the range of concentration which is adequate for normal growth is quite broad, and the nurseryman can do all right with whatever intelligent choice he makes, pending the development of more precise information.

13.62 Chemicals Used to Supply Nutrients

A number of chemical compounds can be used to supply the nutrients elements and acidity. Often there is a choice of several almost equally suitable compounds (table 13-8). A number of these compounds are acids. Table 13-9 shows the safety hazards and cost of the four most commonly available acids.

Most water supplies will need acidification in order for the water to provide nutrient solutions suitable for optimizing tree growth. The amount of acid to do this is found by reading the titration table for the water at the site. The question then becomes which acid to use. For acidification of water in a bare-root nursery, the cost of the acid may dictate use of sulfuric acid, the cheapest common acid. However, in the greenhouse nursery the volume of water used is only 10% of that used in a bare-root operation for the same number of trees, so the most expensive acids can be used economically.

Table 13-5.—Average foliar mineral element concentrations in percent or parts per million oven dry weight from monthly sampling May through October (Smith 1967, Powers 1976).

	Percent					ppm						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Mo	Zn	Al
Average for deciduous plants[1]	2.56	.33	1.27	1.80	.39	222	227	37	21	3.60	52	463
Broadleaf evergreens[2]	2.16	.27	1.09	1.49	.29	300	338	39	23	3.00	66	469
Narrowleaf evergreens[3]	2.18	.33	1.05	.89	.19	197	189	34	18	1.66	56	279

[1] *Species sampled:* *Betula pendula*, *Cornus florida*, *Crataegus phaenopyrum*, *Liquidambar styraciflua*, *Prunus subhirtella 'Pendula'*, *Pyrus calleryana 'Bradford'*, *Sorbus aucuparia*, *Rhododendron 'Cascade'*, *Chaenomeles speciosa*, *Cotoneaster apiculata*, *Euonymis alatus 'Compacta'*, *Syringa vulgaris 'Edith Cavell'*, *Viburnum plicatum*

[2] *Species sampled:* *Euonymus fortunei vegetus*, *Hedera helix*, *Ilex crenata 'Convexa'*, *Ilex opaca*, *Leucothe catesbei*, *Pieris japonica*, *Pyracantha coccinea 'Lalandi'*, *Rhododendron 'Nova Zembla'*, *Vinca minor*

[3] *Species sampled:* *Juniperus chinensis 'Pfitzeriana'*, *Picea omorika*, *Pinus strobus*, *Taxus media 'Browni'*, *Taxus media 'Hicksi'*, *Thuja occidentalis 'Pyramidalis'*, *Tsuga canadensis*

Table 13-6.—Sources of information on nutrient element content by foliar analysis and optimum nutrient solutions for individual species.

Species	Elements	Authority
Betula papyrifera	N, P, K	Bjorkbom (1973 a & b)
Betula verricosa	N, P, K, Ca, Mg, S	Ingestad (1962)
"	N, P, K, Ca, Mg, S	Ingestad (1970, 1971)
Picea abies	N, P, K, Ca, Mg, S	Touzet and Heinrich (1970)
"	N, P, K, Ca, Mg, S	Ingestad (1962)
Picea glauca	N, P, K, Ca, Mg, S	Hocking (1971)
Picea mariana	N, P, K, Ca, Mg	Stewart and Swan (1970)
Picea pungens	N, P	Esau (1970)
Picea sitchensis	N, P, K, Ca, Mg	van den Driessche (1969a)
Pinus banksiana	N, P, K, Ca, Mg	Stewart and Swan (1970)
Pinus contorta	N, P, K, Ca, Mg, S	Hocking (1971)
Pinus densiflora	N, P, K	Kawada (1968)
Pinus larico	N, P, K, Ca, Mg, S	Touzet and Heinrich (1970)
Pinus pinaster	N, P, K, Ca, Mg, S	Touzet and Heinrich (1970)
Pinus strobus	N, P	Lister et al. (1968)
"	N, P, K, Ca, Mg, S	Touzet and Heinrich (1970)
"	All	Schomaker (1969)
Pinus sylvestris	N, P, K, Ca, Mg, S	Ingestad (1962)
Populus deltoides	N, P, K	Bonner and Broadfoot (1967)
"	N, K	Baker and Randall (1975)
"	N, P, K, Ca, Mg	Phares (1966)
Populus spp.	N, P, K, Ca, Mg	Einspahr (1971)
"	N, P, K, Ca, Mg	Garbaye (1972)
Pseudotsuga menziesii	N, P, K, Ca, Mg	van den Driessche (1969a)
"	N, P, K, Ca, Mg, S	Touzet and Heinrich (1969)
"	All	Krueger (1967)
Vaccinium myrtillus	N, P, K, Ca, Mg	Ingestad (1973)
Vaccinium vitis	N, P, K, Ca, Mg	"

When a considerable amount of acid is used, it should contribute nutrient ions that are needed. Chlorine (as Cl^-) is needed in very small quantities, and this is already present in the water or present as impurities in the other fertilizer chemicals used. Thus, it makes little sense to use hydrochloric acid. It is included in table 13-9 for completeness, but is never recommended. Many water supplies will also contain enough sulfur (as $SO_4^=$). In these cases, sulfuric acid contributes additional salt, which is not beneficial. Lower cost may still dictate its use, however, especially when the water is acidified separately and a commercial fertilizer mix is used.

Phosphoric and nitric acids are recommended because they always contribute needed nutrient ions. Whenever possible, phosphoric acid should be used, because it is the safest of the four common acids to handle, especially by personnel with limited training (Jaramillo and Owston 1977). It does not react violently with water, there are no toxic fumes, it is not an oxidizer, and it does the least damage if it touches the skin. Its major drawback is relatively high cost.

Table 13-7.—Optimum nutrient solutions for various species. Blanks indicate elements not tested for optimality; not lack of the element.

Species	Nutrient element concentration (ppm)													Authority
	N	P	K	Ca	Mg	S	Fe	B	Mn	Cl	Zn	Cu	Mo	
Barley and tomatoes	210	31	240	170	48	64	4	0.50	0.50	4	0.05	0.02	0.010	Hoagland and Arnon (1938)
Betula papyrifera	400	50	35	120	48	64	3	0.50	0.50		0.06	0.06	0.009	Bjorkbom (1973b)
Betula verricosa	140	100	175	120	48	64	2.80	0.50	0.50		0.06	0.06	0.009	Ingestad (1962)
Picea abies	50	10	50	40	15	20	0.93	0.17	0.17		0.02	0.02	0.003	Ingestad (1962)
Picea glauca	112	31	156	80	48	150								Hocking (1971)
Picea mariana	100 +	10 +	10 +	40 +	10 +									Stewart and Swan (1970)
Picea mariana									0.10					Morrison and Armson (1968)
Picea sitkensis	50	30 +	20											van den Driessche (1969a)
Pinus banksiana	100 +	10 +	10 +	40 +	10 +									Stewart and Swan (1970)
Pinus banksiana									0.10					Morrison and Armson (1968)
Pinus contorta	112	31	156	80	48	150								Hocking (1971)
Pinus strobus	280	93	273	200	73	96								Schomaker (1969)
Pinus sylvestris	50	20	50	40	15	20	0.93	0.17	0.17		0.02	0.02	0.003	Ingestad (1962)
Populus deltoides	100	75	100											Bonner and Broadfoot (1967)
Populus deltoides	100	18	120	202 +	134 +									Phares (1966)
Populus tremuloides	105	22	75	46	21									Einspahr (1971)
Pseudotsuga menziesii	100	30 +	30											van den Driessche (1969a)

Nitric acid is the second choice. It is usually used where more acidification is required beyond the amount of phosphoric acid required to supply needed phosphorus. Sufficient nitric acid is added to achieve the target pH, but needed nitrogen beyond this point is normally provided by other compounds, such as ammonium nitrate, ammonium sulfate, ammonium phosphate, calcium nitrate, or potassium nitrate.

Potassium can be supplied as potassium nitrate, phosphate, sulfate, or carbonate. Potassium chloride should not be used for the same reason that hydrochloric acid is not used for acidification: it increases the salt concentration by adding ions that are not needed. Potassium carbonate is used to raise the pH and introduce potassium without adding other anions. Addition of potassium phosphate alters pH of the solution, and this usually is adjusted with acids.

Magnesium can be supplied as magnesium sulfate or as dolomite, which is calcium magnesium carbonate ($CaCO_3MgCO_3$). Dolomite raises the pH of the water and is not soluble, except in acid. Therefore, magnesium is usually supplied as magnesium sulfate, even if there is already a surplus of sulfate in the solution.

The choice of compounds containing micronutrients is simpler than for macronutrients, because only one nutrient element is dealt with per compound. Iron is supplied as a chelate or as ferrous sulfate. The chelate is preferred, because it stays in solution better, and thus is more available to the plant. Chelates containing different percentages of iron are on the market, and these may be used interchangeably.

Potassium chloride is used to supply a small amount of chlorine, if needed. This is not likely to be needed, because fertilizer grade chemicals commonly contain chlorides as impurities.

Boron is supplied as boric acid. Borax (sodium tetraborate) can also be used, but it is alkaline in reaction, and there is no need to add sodium.

Zinc, copper, and manganese are supplied as sulfates, because they are soluble but not deliquescent, stable, and readily available.

Molybdenum is added as ammonium molybdate for the same reasons, but may also be added as molybdic acid or sodium molybdate.

13.63 Proportions of the Ions in the Solution

Plants take up some ions rapidly and other ions more slowly. When there is not a balance in the rate of uptake between nutrient anions and cations, the pH of the medium changes. When more anions than cations are taken up, the pH rises. When the reverse is true, it falls. Therefore, it is desirable to balance the rapidity of cation and anion uptake so that the

Table 13-8.—Nutrient element content of common fertilizer chemicals.

	Fraction of element in compound							
Compound	(NO_3) N	(NH_4) N	P	K	S	Ca	Mg	M.W.
KNO_3	0.139			0.386				101
NH_4NO_3	0.175	0.175						80
$Ca(NO_3)_2 \cdot 4H_2O$	0.119					0.169		236
$(NH_4)_2HPO_4$		0.212	0.235					132
$(NH_4)_2SO_4$		0.212			0.242			132
HNO_3	0.222							63
H_3PO_4			0.316					98
KH_2PO_4			0.228	0.287				136
$Ca(H_2PO_4)_2 \cdot H_2O$			0.246			0.159		252
K_2CO_3				0.565				138
$CaCO_3 \cdot MgCO_3$						0.217	0.130	184
$MgSO_4 \cdot 7H_2O$					0.130		0.097	246
K_2SO_4				0.448	0.184			174
H_2SO_4					0.326			98
P_2O_5			0.437					142
K_2O				0.830				94
NO_3^-	0.226							62
NH_4^+		0.778						18
$SO_4^=$					0.333			96

	Fraction of Element in Compound							
Compound	Fe	Cl	B	Mn	Zn	Cu	Mo	M.W.
$FeSO_4 \cdot 7H_2O$	0.231							278
Fe Chelate (10%)	0.100							—
KCl		0.480						75
H_3BO_3			0.177					63
$MnSO_4 \cdot 4H_2O$				0.247				223
$ZnSO_4$					0.404			161
$CuSO_4 \cdot 5H_2O$						0.256		250
$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$							0.544	1,212

Table 13-9.—Characteristics of the four common mineral acids.

Acid	Cost	Reaction with water	Toxic fumes	Contact Hazard		Strong oxidizer	Nutrient element needed
				Concentrated	Dilute		
Sulfuric	low	violent	no	chars flesh	dissolves clothes	yes	yes
Nitric	moderate	some heating	yes	dissolves flesh	stains skin yellow	yes	yes
Phosphoric	high	none	no	stings in cuts	none	no	yes
Hydrochloric	moderate	none	yes	stings	none	no	no

pH remains stable. The most rapidly absorbed nutrient ions are potassium, ammonium, and nitrate. It is possible to achieve stability without changing the proportion of elements in solution by adjusting the ratio of ammonium nitrogen to nitrate nitrogen in the fertilizer solution. For those tree species that have been studied, a favorable ratio is about 30% N as NH_4^+ and 70% N as NO_3^- (Ingestad 1970, 1971).

Occasionally, there may be so much of one element in the water that the uptake of the other elements is suppressed. For instance, there is competition between molybdenum and manganese (Matkin 1976), between iron and the other heavy metals (Daniels and Struckmeyer 1973, Beauchamp and Rossi 1972, Rogers 1973, Agarwala et al. 1977), between zinc and manganese (Singh and Steenberg 1974), and between calcium and magnesium (Phares 1966). Generally, the ratio of calcium to magnesium should be kept between 2:1 and 6:1. Another rule is: if the concentration of one ion is three to five times the recommended concentration, it may be necessary to increase the concentration of the competing ion to enable it to be taken up in sufficient amounts.

Water test results should be supplied for the specified ions in parts per million (ppm) or mg/l, which is the same (section 13.11). The optimum nutrient concentration targets provided here are in ppm of the solution.

The titration table provides the milliequivalents (meq) of strong acid to bring about a certain change in the pH of the test water. For nitric acid, 1 meq equals the gram molecular weight (MW) (63) in mg/l.

For sulfuric acid, 1 meq equals half the MW (98 ÷ 2 = 49 mg/l). However, phosphoric acid is a weak acid and the acidity released is a function of pH. Nutrient solutions are rarely formulated to be below pH 4 or above pH 7.5. For nutrient solutions between pH 4 and 5, it can be assumed that 1 MW yields 1 equivalent of phosphoric acid. Between pH 5.0 and 7.5, 1 MW yields between 1 and 2 equivalents. Appropriate factors can be interpolated from table 13-10.

13.64 Nutrient Solution Formulation: An Example

To formulate nutrient solutions, the nurseryman must first have a chemical analysis and titration table for his water supply (section 13.1). As examples an analysis and titration table for Bottineau, N. Dak. city water is given in table 13-11 and table 13-12, respectively. Next, select target concentrations for each nutrient ion and a target pH for the nutrient solution. These may vary according to the crop to be grown, the experience of the nurseryman, and the nutrient research information available. The targets used successfully by Tinus in western conifer culture are listed in table 13-13. The chemical compounds to be selected and the quantity needed to produce the target concentrations of nutrient ions are outlined below. Figure 13-2 is provided as a worksheet. The following example is for preparation of the Tinus high N solution formulated using Bottineau water.

Table 13-10.—Equivalents of acid per gram molecular weight of phosphoric acid (H_3PO_4) as a function of pH.

pH	Acid equivalents
5.0	1.05
5.4	1.1
5.7	1.2
6.0	1.3
6.3	1.5
6.6	1.7
6.9	1.8
7.2	1.9
7.6	1.95

Table 13-11.—Analysis of Bottineau, N. Dak. city water on July 27, 1970.

	(ppm)
Total solids by ion summation	1,245
Total alkalinity as $CaCO_3$	475
pH	7.5
Iron (Fe)	0.20
Manganese (Mn)	1.37
Calcium (Ca)	212
Magnesium (Mg)	33
Chloride (Cl)	1
Sulfate (SO_4)	366
Nitrate (NO_3)	1
Potassium (K)	0
Sodium (Na)	60

Table 13-12.—Titration table of Bottineau, N. Dak. city water.

pH	Titrant used meq/liter	pH	Titrant used meq/liter
7.1	0.00	5.9	7.22
7.0	0.50	5.8	7.77
6.9	0.90	5.7	8.10
6.8	1.40	5.6	8.42
6.7	1.90	5.5	8.65
6.6	2.53	5.4	8.96
6.5	3.10	5.3	9.14
6.4	3.82	5.2	9.28
6.3	4.59	5.1	9.40
6.2	5.61	5.0	9.52
6.1	6.13	4.9	9.58
6.0	6.68		

Table 13-13.—Target nutrient ion concentrations successfully used for western conifers by Tinus.

Element	Desired concentration (ppm) High N	Low N, High PK
N as NO_3^-	156	12
N as NH_4^+	67	8
P	27	60
K	155	155
Ca	60	60
Mg	40	40
S	63	63
Fe	4	4
Cl	4	4
Mn	0.5	0.5
B	0.5	0.5
Zn	0.05	0.05
Cu	0.02	0.02
Mo	0.01	0.01
pH	5.5	5.5

To begin, fill in the target concentrations on lines 1 and 11 of the worksheet. Next, fill in element concentrations from the water analysis on lines 2 and 12. Notice that the water analysis reports sulfate ($SO_4^=$) and not sulfur (S). Look in table 13-8 for the proportion of sulfur in sulfate. Then (ppm $SO_4^=$) = (proportion of surfur in sulfate) (ppm S).

$$336 \times 0.333 = 122$$

Record 122 in line 2, column 6 of the worksheet. (Notice that this water is quite salty. In fact, if the water were any saltier, it would be good reason to locate the nursery elsewhere. See section 4.15 on water tests before site selection).

On the worksheet, subtract line 2 from 1 and 12 from 11, and write the difference in lines 3 and 13 respectively. Notice that the water already contains more than enough sulfur, calcium, and manganese. It will not be necessary to add these to the nutrient solution. The form should now look like figure 13-3.

Most water supplies will need acidification. The amount of acid needed to reach the desired pH can be obtained from the titration table of the water supply. Table 13-12 shows a titration table for Bottineau, N. Dak. city water supply taken during December. The sample composition will vary somewhat with

column

Line 1	2	3	4	5	6	7	8	9	10	11
	Nutrient Elements (ppm)							Total	Stock soln. x ___	Cpd. com-pat
	(NO_3) N	(NH_4) N	P	K	S	Ca	Mg	Cpd mg/l		
1. Target Conc.										
2. Water anal.										
3. Net to Add										
Cpds. used:	–	–	–	–	–	–	–	–	–	
4.										
5.										
6.										
7.										
8.										
9.										
10. Total										
	Fe	Cl	B	Mn	Zn	Cu	Mo		x___	
11. Target Conc.										
12. Water anal.										
13. Net to Add										
14.										
15.										
16.										
17.										
18.										
19.										
20.										

Figure 13-2.—Worksheet for calculation of fertilizer stock solutions.

column

Line 1	2	3	4	5	6	7	8	9	10	11
	Nutrient Elements (ppm)							Total	Stock soln. x ____	Cpd. com-pat.
	(NO$_3$) N	(NH$_4$) N	P	K	S	Ca	Mg	Cpd mg/l		
1. Target Conc.	156	67	27	155	63	60	48			
2. Water anal.	0	0	0	0	122	212	33			
3. Net to Add	156	67	27	155	0	0	15			
Cpds. used:	–	–	–	–	–	–	–	–	–	–
4.										
5.										
6.										
7.										
8.										
9.										
10. Total										
	Fe	Cl	B	Mn	Zn	Cu	Mo		x____	
11. Target Conc.	4	4	0.5	0.5	0.05	0.02	0.01			
12. Water anal.	0.2	1	0	1.4	0	0	0			
13. Net to Add	3.8	3	0.5	0	0.05	0.02	0.01			
14.										
15.										
16.										
17.										
18.										
19.										
20.										

Figure 13-3.—Worksheet for calculation of fertilizer stock solutions after calculation of net elements to be added.

the season. The nurseryman should be aware of this seasonal variation and be prepared to adjust the amount of acid accordingly. This particular water supply is high in carbonates, which is why it requires so much acid to lower the pH. Most water supplies require less acid. If the target pH is set at 5.5, by reading the titration table we find that 8.65 meq of acid will have to be added to each liter of this water.

Next determine what acid to use (section 13.62). Phosphorus is needed, so, use phosphoric acid first. How much phosphoric acid is needed to supply 27 ppm P? Table 13-8 lists the fractions of nutrient element in a variety of compounds which might be used to supply it. Then:

$$\frac{\text{Amount of Element}}{\text{Fraction of Element in Compound}} = \text{Amount of Compound}$$

$$\frac{27 \text{ ppm P}}{0.316 \text{ P in } H_3PO_4} = 85 \text{ ppm } H_3PO_4$$

On line 4, record H_3PO_4 in column 1, 27 ppm in column 4 under element P, and 85 ppm in column 9 under total compound. To find if 85 ppm of H_3PO_4 is enough acid, it must be converted in milliequivalents of acid:

$$\frac{\text{MW of acid}}{(\text{meq per MW}) \times (\text{amt. of acid})} = \text{acid equivalent}$$

From table 13-8 MW of H_3PO_4 = 98
From table 13-10 at pH 5.5, meq per MW = 1.13
Then:

$$\frac{98}{(1.13) \times (85)} = 1.0 \text{ acid equivalents represented by 85 ppm } H_3PO_4 \text{ at pH 5.5}$$

Since 8.6 meq must be neutralized, then 8.6 − 1.0 = 7.6 more meq/l that must be neutralized with nitric acid.

The molecular weight of nitric acid is 63, so,

$(\text{meq/l}) \times (\text{MW}) = \text{mg/l of acid}$
$(7.6) \times (63) = 479 \text{ mg/l nitric acid to be added.}$

This completes the acid required to lower the pH to 5.5 and to supply 27 ppm P. The nitric acid also adds nitrate nitrogen. The amount is found by multiplying the amount of the acid used by the fraction of N in it from table 13-8. Therefore:

$$(479) \times (0.222) = 106 \text{ ppm } NO_3 \text{ nitrogen.}$$

The figure for the nitric acid should now be added to the worksheet. On line 5, enter HNO_3 in column 1, 106 in column 2, and 479 in column 9.

Notice that the nitrogen requirement for both nitrate and ammonium nitrogen is not yet fulfilled, so next, seek a compound to fill that need and perhaps another macronutrient. A lot of potassium is needed. Either potassium nitrate, phosphate, sulfate, or carbonate could be used, but for reasons discussed in section 13.63 and because of the need for more nitrogen, potassium nitrate (KNO_3) is chosen to supply all of the potassium. On line 6, enter KNO_3 in column 1 and 155 in column 5.
Then:

$$KNO_3 \text{ required} = \frac{\text{amount of K needed}}{\text{fraction of K in } KNO_3}$$

$$= \frac{155}{0.386} = 401 \text{ ppm}$$

Enter 401 in column 9 on line 6.

The next question is how much nitrate N did the KNO_3 supply.

$$(\text{amount of } KNO_3)\ (\text{fraction of N in } KNO_3) = (\text{amount of N})\ 401 \times 0.139 = 56$$

Record 56 on line 6, column 2. Note there is now a little more nitrate than the target (162 ppm versus 156 ppm), but this is inconsequential.

Magnesium is most conveniently supplied as a sulfate, even though there is a surplus of sulfate. To supply 15 ppm Mg, we need:

$$\frac{15}{0.097} = 154 \text{ ppm } MgSO_4$$

(where 0.097 is the percentage of Mg in $MgSO_4$ from table 13-8).

On line 7, record $MgSO_4$ in column 1, 15 in column 8, and 154 in column 9. The $MgSO_4$ is also supplying sulfur, so,

$$(154 \text{ ppm } MgSO_4) \times 0.130 = 20 \text{ ppm S}$$

(0.130 is the fraction of S in $MgSO_4$ from table 13-8).

Enter 20 on line 7, column 6 of the worksheet.

As discussed in section 13.63, the proportions of nitrogen types in the nutrient solution should be about 30% N as NH_4^+ and 70% N as NO_3^-. In this example, an ammonium salt is needed. Ammonium phosphate, sulfate, or nitrate may be used. The phosphate will affect the pH, and there is already enough P present. There is already a surplus of sulfate, and there will be a surplus of nitrate N, if ammonium nitrate is selected. No choice is clearly best. A decision is made to accept a moderate surplus of nitrate rather than add to an already large surplus of sulfate or throw off pH control. To yield 67 ppm of ammonium N we need:

$$\frac{67}{0.175} = 383 \text{ mg/l of } NH_4NO_3$$

(where 0.175 is the percentage of NH_4, nitrogen is ammonium nitrate, from table 13-8). This salt also yields nitrate N in the amount: 383 x 0.175 = 67 ppm NO_3 in nitrogen.

On line 8 enter NH_4NO_3 in column 1, 67 in both columns 2 and 3, and 383 in column 9 on the worksheet. This completes the formulation of the macronutrients.

The choice of salts to satisfy micronutrient needs is simpler, because we deal with only one nutrient element per salt. There are few enough accompanying ions that they may be neglected, because they contribute little to either salt buildup or amount of other mineral nutrients.

Iron is usually supplied as a chelate (section 13.62). Chelates come in different percentages of iron. To obtain the amount of chelate to use, divide the ppm iron desired by the fraction of the iron in the compound. For this example, we use a 10% compound:

$$\frac{3.8}{0.10} = 38 \text{ ppm chelate}$$

On line 14, enter Fe chelate (10%) in column 1, 3.8 in column 2, and 38 in column 9 on the worksheet.

Potassium chloride is used to supply the small amount of chlorine required. Boron is supplied as boric acid. Zinc and copper are supplied as sulfates. Molybdenum is added as ammonium molybdate. The amount of compound required to give the desired concentration of these micronutrient elements is calculated as for iron, using the same formula and table 13-8, and the information is recorded on the worksheet which should now look like figure 13-4.

13.65 Nutrient Concentrate Formulation

In column 9 of figure 13-4, the concentrations of compounds required to give the desired nutrient solution are recorded. This is what the seedlings will receive, but the nutrients will be injected into the irrigation water from concentrated or stock solutions. To determine the concentration of salts in the stock solutions, the dilution factor or injection ratio must be known. For the macronutrients, this normally ranges from 100:1 to 400:1. At ratios above 400:1, solubility becomes a problem, and the salts may not dissolve completely. At ratios below 100:1, the volume of stock solution required may become a nuisance to make up and store. Anything in between these extremes is usually satisfactory. There may not be a choice if the injector on hand is fixed ratio type.

For this example, 200:1 was picked for the macronutrients. Column 9 figures are concentrations in milligrams per liter. Multiply each macronutrient value by the dilution factor (200) and divide by 1,000. Enter the values in column 10, which is the stock solution concentration in grams per liter.

Continue the procedure for the micronutrients. If all nutrients are to be combined into a single stock solution, then the dilution ratio must be the same for all. If the micronutrients are in a separate stock solution from the macronutrients, they may have a dilution factor in excess of 1,000:1. Here, the upper limit is not the solubility of the salts, because there is so little of them, but the ability of the injector to operate at those rates. The advantage of a more concentrated solution is that there is less of it to handle, and it is usually made up less often.

If we pick 1,000:1, then the arithmetic is simple. Multiplying by the dilution factor (1,000) and dividing by 1,000 gives the micronutrient stock solution values in grams per liter (column 10).

13.66 Nutrient Salt Compatibility

To determine if the nutrient salts must be in several different nutrient solutions and how to divide them, consult table 13-14. For each salt or acid selected, follow across the row to see with which salts it is not compatible. In the example, notice first that at least one stock solution will be strongly acid because of the nitric and phosphoric acids in it. All of the macronutrient compounds are stable and soluble in strong acid, so, label them "A" in column 11. All of the micronutrients are also soluble in acid, but the iron chelate will be destroyed. It must, therefore, be in a separate solution. Label it "B" in column 11. That means there must be at least two stock solutions. Careful examination of table 13-14 shows no other incompatibilities, so two stock solutions are all that is needed. The rest of the micronutrients could go in either solution (label them AB), but because they are needed in such small amounts, it is more convenient to put them in with the iron. To make sure the copper and zinc stay in solution in the presence of boric acid, add 5 ml/l of nitric acid. At a dilution factor of 1,000:1, this will add a negligible amount of nitrate to the nutrient solution. The worksheet is now complete and should look like figure 13-5.

13.67 The Nutrient Recipe and Mixing

The nutrient recipe is the result of the size of the batch of nutrient concentrate solution the nurseryman decides to make up at each mixing. In our example, suppose we want 100 l for the acid solution, then the figures for each compound in the grams per

column

Line 1	2	3	4	5	6	7	8	9	10	11
	Nutrient Elements (ppm)							Total	Stock soln. x ___	Cpd compat.
	(NO_3) N	(NH_4) N	P	K	S	Ca	Mg	Cpd mg/l		
1. Target Conc.	156	67	27	155	63	60	48			
2. Water anal.	0	0	0	0	122	212	33			
3. Net to Add	156	67	27	155	0	0	15			
Cpds. used:	–	–	–	–	–	–	–	–	–	–
4. H_3PO_4			27					85		
5. HNO_3	106							479		
6. KNO_3	56			155				401		
7. $MgSO_4$				20			15	154		
8. NH_4NO_3	67	67						383		
9.										
10. Total	229	67	27	155	142	212	48			
	Fe	Cl	B	Mn	Zn	Cu	Mo		x ___	
11. Target Conc.	4	4	0.5	0.5	0.05	0.02	0.01			
12. Water anal.	0.2	1	0	1.4	0	0	0			
13. Net to Add	3.8	3	0.5	0	0.05	0.02	0.01			
14. Fe chelate	3.8							38		
15. KCl		3						6		
16. H_3BO_3			0.5					2.8		
17. $ZnSO_4$					0.05			0.123		
18. $CuSO_4$						0.02		0.078		
19. $(NH_4)_6Mo_7O_{24}$							0.01	0.018		
20.										

Figure 13-4.—Worksheet for calculation of fertilizer stock solutions after selection of compounds.

column

Line 1	2	3	4	5	6	7	8	9	10	11
	Nutrient Elements (ppm)							Total	Stock soln. x 200	Cpd. compat.
	(NO_3) N	(NH_4) N	P	K	S	Ca	Mg	Cpd mg/l		
1. Target Conc.	156	67	27	155	63	60	48			
2. Water anal.	0	0	0	0	122	212	33			
3. Net to Add	156	67	27	155	0	0	15	mg/l or ppm	g/l	
Cpds. used:	–	–	–	–	–	–	–	–	–	–
4. H_3PO_4			27					85	17.0	A
5. HNO_3	106							479	95.8	A
6. KNO_3	56			155				401	80.2	A
7. $MgSO_4$					20		15	154	30.8	A
8. NH_4NO_3	67	67						383	76.6	A
9.										
10. Total	229	67	27	155	142	212	48			
	Fe	Cl	B	Mn	Zn	Cu	Mo		x 1000	
11. Target Conc.	4	4	0.5	0.5	0.05	0.02	0.01			
12. Water anal.	0.2	1	0	1.4	0	0	0			
13. Net to Add	3.8	3	0.5	0	0.05	0.02	0.01	ppm	g/l	
14. Fe chelate	3.8							38	38	B
15. KCl		3						6	6	AB
16. H_3BO_3			0.5					2.8	2.8	AB
17. $ZnSO_4$					0.05			0.123	0.123	AB
18. $CuSO_4$						0.02		0.078	0.078	AB
19. $(NH_4)_6Mo_7O_{24}$							0.01	0.018	0.018	AB
20.										

Figure 13-5.—Complete worksheet for calculation of fertilizer stock solutions.

Table 13-14.—Compatibility of nutrient compounds in concentrated stock solutions. An "X" at the intersection of a row and a column means the compounds are not compatible. "A" means soluble in strongly acid solutions only. "N" means stable in neutral or only slightly acid solutions, but not strong acid. "S" indicates strong heating and effervescence when the two are combined. Mixing should be done with great caution. Where there is no letter at the intersection point, the compounds are compatible.

	Compounds																				
Compounds	KNO_3	NH_4NO_3	$Ca(NO_3)_2 \cdot 4H_2O$	$(NH_4)_2HPO_4$	$(NH_4)_2SO_4$	HNO_3	H_3PO_4	KH_2PO_4	$Ca(H_2PO_4)_2 \cdot H_2O$	K_2CO_3	$CaCO_3 \cdot MgCO_3$	$MgSO_4 \cdot 7H_2O$	K_2SO_4	H_2SO_4	$FeSO_4 \cdot 7H_2O$	Fe chelate	KCl	H_3BO_3	$MnSO_4 \cdot 4H_2O$	$ZnSO_4$	$CaSO_4 \cdot 5H_2O$
KNO_3	—																				
NH_4NO_3		—																			
$Ca(NO_3)_2 \cdot 4H_2O$			—																		
$(NH_4)_2HPO_4$			A	—																	
$(NH_4)_2SO_4$					—																
HNO_3						—															
H_3PO_4			A				—														
KH_2PO_4			A					—													
$Ca(H_2PO_4)_2 \cdot H_2O$				A	X				—												
K_2CO_3			X			S	S		X	—											
$CaCO_3 \cdot MgCO_3$	A	A	A	A	A	A	A	A	A	A	—										
$MgSO_4 \cdot 7H_2O$			X	A					A		A	—									
K_2SO_4			X								A		—								
H_2SO_4			A							S	A			—							
$FeSO_4 \cdot 7H_2O$			A						A		A				—						
Fe chelate						N	N				A			N		—					
KCl											A						—				
H_3BO_3			A						A		A				A			—			
$MnSO_4 \cdot 4H_2O$				A			A		A	A	A							A	—		
$ZnSO_4$				A			A		A	A	A							A		—	
$CaSO_4 \cdot 5H_2O$				A			A		A	A	A							A			—
$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$										A	A										

liter column of the worksheet would be multiplied by 100. For instance for $MgSO_4$, 30.8 g/l would become 3,080 g or 3.08 kg.

To make up the solutions, dry chemicals are weighed and dissolved in about three-fourths of the water required. If hot water is available, they will dissolve quicker. After solution is complete, the liquid acids are added, and the solution is made up to final volume. Column 10 of the worksheet lists the weight of chemical needed, but it is more convenient to measure liquids by volume. Commercial acids come in varying strengths which are measured in percent, specific gravity, or degrees Baumé (Bé). Use tables 13-15, 13-16, and 13-17 to determine grams of pure acid per liter of commercial acid. Divide the weight of acid by this figure to get the volume required; (weight of commercial acid in grams) ÷ (grams per liter) = liters of acid. In our example, suppose 75% phosphoric acid is used, and 17.0 gm/l is needed from column 10 of the worksheet. Then: 17.0/1,184 = 0.014 or 14 ml per liter of stock solution. Suppose the nitric acid is 42° Bé and 95.8 gm/l is needed, so, 95.8/946 = 0.101 liters or 101 ml per liter of stock solution.

13.68 A Second Example of Nutrient Solution Preparation

The following is a second example presented in briefer form using data from the Mount Sopris Nursery at Carbondale, Colo. If the reader can follow through the procedures outlined in both of the examples, he is ready to formulate nutrient solutions for his own nursery. The water analysis and target concentrations for nutrient ions are shown in figure 13-6, and the water titration in table 13-18.

Calculations for macronutrients.--

1. HNO_3 will be used to lower pH to the optimum 5.5 and add needed nitrogen. For nitric acid, 1 meq = 63 mg/l (parts per million) (section 13.63), and we need 9.54 meq to lower the solution to pH 5.5 (table 13-18). Therefore, (63) x (9.54) = 601 mg/l. (601) x (0.222 N) = 133 ppm N.
2. KNO_3 will be used next to add nitrogen and potassium. We need 145 ppm K and know that KNO_3 is 0.386 K from table 13-8. Therefore, (145 parts per million) ÷ (0.386) = 376 mg/l

column

Line 1	2	3	4	5	6	7	8	9	10	11
	Nutrient Elements (ppm)							Total	Stock soln. x ____	Cpd. com-pat.
	(NO_3) N	(NH_4) N	P	K	S	Ca	Mg	Cpd mg/l		
1. Target Conc.	140	60	30	150	40	100	50			
2. Water anal.	0	0	0	5	16	160	29			
3. Net to Add	140	60	30	145	24	0	21			
Cpds. used:	–	–	–	–	–	–	–	–	–	–
4.										
5.										
6.										
7.										
8.										
9.										
10. Total										
	Fe	Cl	B	Mn	Zn	Cu	Mo		x____	
11. Target Conc.	4	4	0.5	0.5	0.05	0.02	0.01			
12. Water anal.	0	3	0.1	0	0	0	0			
13. Net to Add	4	1	0.4	0.5	0.05	0.02	0.01			
14.										
15.										
16.										
17.										
18.										
19.										
20.										

Figure 13-6.—Worksheet for calculation of fertilizer stock solutions with target concentrations and Mount Sopris water analysis entered.

KNO_3 required. the amount of nitrogen gained will be (376 mg/l KNO_3) x (0.139) = 52 ppm N.

3. Diammonium phosphate $(NH_4)_2HPO_4$ will be added next to meet the phosphorus demand as well as complete the nitrogen requirement.
   (30 ppm P) ÷ (0.235 P) = 128 mg/l
   $(NH_4)_2HPO_4$
   (128 mg/l $(NH_4)_2HPO_4$) x (0.212 N) =
   27.0 ppm N
4. Magnesium and sulfur are the only two remaining macroelements, and they both can be supplied by magnesium sulfate.
   (21 ppm Mg) ÷ (0.097 Mg) = 216 mg/l
   $MgSO_4 \cdot 7H_2O$
   (216 mg/l $MgSO_4$) x (0.130 S) = 28 ppm S

Calculations for micronutrients.—

1. We need 4 ppm Fe
   (4 ppm Fe) ÷ (0.10 Fe) = 40 mg/l Fe chelate
2. We need 1.0 ppm Cl
   (1.0 ppm Cl) ÷ (0.48 Cl) = 2.1 Mg/l KCl
3. We need 0.4 ppm B
   (0.4 ppm B) ÷ (0.177) = 2.2 mg/l H_3BO_3

Table 13-15.—Phosphoric Acid. Relation between degrees Baumé (Bé), specific gravity (Sp. gr.), percent acid, and grams of acid per liter (gm/l) (Hodgman et al. 1953).

Bé	Sp. gr.	Percent H_3PO_4	gm/l
0.6	1.0038	1	10.04
1.3	1.0092	2	20.18
2.8	1.0200	4	40.80
4.3	1.0309	6	61.85
5.8	1.0420	8	83.36
7.3	1.0532	10	105.3
8.8	1.0647	12	127.8
10.3	1.0764	14	150.7
11.8	1.0884	16	174.1
13.3	1.1008	18	198.1
14.8	1.1134	20	222.7
16.3	1.1263	22	247.8
17.8	1.1395	24	273.5
19.2	1.1529	26	299.8
20.7	1.1665	28	326.6
22.2	1.1805	30	354.2
25.8	1.2160	35	425.6
29.4	1.2540	40	501.6
32.9	1.2930	45	581.9
36.4	1.3350	50	667.5
39.9	1.3790	55	758.5
43.3	1.4260	60	855.6
46.7	1.4750	65	958.8
50.0	1.5260	70	1,068
53.2	1.5790	75	1,184
56.2	1.6330	80	1,306
59.2	1.6890	85	1,436
62.0	1.7460	90	1,571
63.1	1.7700	92	1,628
64.2	1.7940	94	1,686
65.3	1.8190	96	1,746
66.4	1.8440	98	1,807
67.5	1.8700	100	1,870

Table 13-16.—Nitric Acid. Relation between degrees Baumé (Bé), specific gravity (Sp. gr.), percent acid, and grams of acid per liter (gm/l) (Hodgman et al. 1953).

Bé	Sp. gr.	Percent HNO_3	gm/l
31.50	1.2775	43.89	560.6
31.75	1.2804	44.34	568.0
32.00	1.2832	44.78	574.6
32.25	1.2861	45.24	581.8
32.50	1.2889	45.68	588.8
32.75	1.2918	46.14	596.0
33.00	1.2946	46.58	603.0
33.25	1.2975	47.04	610.3
33.50	1.3004	47.49	617.6
33.75	1.3034	47.95	625.0
34.00	1.3063	48.42	632.6
34.25	1.3093	48.90	640.2
34.50	1.3122	49.35	647.6
34.75	1.3152	49.83	655.4
35.00	1.3182	50.32	663.0
35.25	1.3212	50.81	671.3
35.50	1.3242	51.30	679.3
35.75	1.3273	51.80	687.5
36.00	1.3303	52.30	695.7
36.25	1.3334	52.81	704.2
36.50	1.3364	53.32	712.6
36.75	1.3395	53.84	721.2
37.00	1.3426	54.36	729.8
37.25	1.3457	54.89	738.7
37.50	1.3488	55.43	747.6
37.75	1.3520	55.97	756.7
38.00	1.3551	56.52	765.9
38.25	1.3583	57.08	775.3
38.50	1.3615	57.65	784.9
38.75	1.3647	58.23	794.7
39.00	1.3679	58.82	804.6
39.25	1.3712	59.43	814.9
39.50	1.3744	60.06	825.5
39.75	1.3777	60.71	836.4
40.00	1.3810	61.38	847.7
40.25	1.3843	62.07	859.2
40.50	1.3876	62.77	871.0
40.75	1.3909	63.48	882.9
41.00	1.3942	64.20	895.1
41.25	1.3976	64.93	907.5
41.50	1.4010	65.67	919.4
41.75	1.4044	66.42	932.8
42.00	1.4078	67.18	945.8
42.25	1.4112	67.95	958.9
42.50	1.4146	68.73	972.3
42.75	1.4181	69.52	985.9
43.00	1.4216	70.33	999.8
43.25	1.4251	71.15	1,014.0
43.50	1.4286	71.98	1,028.3
43.75	1.4321	72.82	1,042.9
44.00	1.4356	73.67	1,057.6
44.25	1.4392	74.53	1,072.6
44.50	1.4428	75.40	1,087.9
44.75	1.4464	76.28	1,103.3
45.00	1.4500	77.17	1,119.0
45.25	1.4536	78.07	1,134.8

4. We need 0.5 ppm Mn
   (0.5 ppm Mn) ÷ (0.247 Mn) = 2.02 mg/l $MnSO_4$
5. We need 0.05 ppm Zn
   (0.05 ppm Zn) ÷ (0.404 Zn) = 0.12 mg/l $ZnSO_4$
6. We need 0.02 ppm Cu
   (0.02 ppm Cu) ÷ (0.256 Cu) = 0.8 mg/l $CuSO_4$
7. We need 0.01 ppm Mo
   (0.01 ppm Mo) ÷ (0.544 Mo) = 0.02 mg/l $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$

Table 13-17.—Sulfuric Acid. Relation between degrees Baumé (Bé), specific gravity (Sp. gr.), percent acid, and grams of acid per liter (gm/l) (Hodgman et al. 1953).

Bé	Sp. gr.	Percent H_2SO_4	gm/l
44.7	1.4453	55	749.9
45.4	1.4557	56	815.2
46.1	1.4662	57	835.7
46.8	1.4768	58	856.5
47.5	1.4875	59	877.6
48.2	1.4983	60	899.0
48.9	1.5091	61	920.6
49.6	1.5200	62	942.4
50.3	1.5310	63	964.5
51.0	1.5421	64	986.9
51.7	1.5533	65	1,010
52.3	1.5646	66	1,033
53.0	1.5760	67	1,056
53.7	1.5874	68	1,079
54.3	1.5989	69	1,103
55.0	1.6105	70	1,127
55.6	1.6221	71	1,152
56.3	1.6338	72	1,176
56.9	1.6456	73	1,201
57.5	1.6574	74	1,226
58.1	1.6692	75	1,252
58.7	1.6810	76	1,278
59.3	1.6927	77	1,303
59.9	1.7043	78	1,329
60.5	1.7158	79	1,355
61.1	1.7272	80	1,382
61.6	1.7383	81	1,408
62.1	1.7491	82	1,434
62.6	1.7594	83	1,460
63.0	1.7693	84	1,486
63.5	1.7786	85	1,512
63.9	1.7872	86	1,537
64.2	1.7951	87	1,562
64.5	1.8022	88	1,586
64.8	1.8087	89	1,610
65.1	1.8144	90	1,633
65.3	1.8195	91	1,656
65.5	1.8240	92	1,678
65.7	1.8279	93	1,700
65.8	1.8312	94	1,721
65.9	1.8337	95	1,742
66.0	1.8355	96	1,762
66.0	1.8364	97	1,781
66.0	1.8361	98	1,799
65.9	1.8342	99	1,816
65.8	1.8305	100	1,831

Table 13-18.—Titration of Mt. Sopris Nursery irrigation water with 0.02N sulfuric acid. (Courtesy of Thomas Landis.)

pH	Titrant used ml	Titrant used meq/l	pH	Titrant used ml	Titrant used meq/l
8.0	0.0	0.00	6.2	43.0	8.60
7.9	5.0	1.00	6.1	43.8	8.76
7.8	10.4	2.08	6.0	44.7	8.94
7.7	15.0	3.00	5.9	45.3	9.06
7.6	18.7	3.74	5.8	46.0	9.20
7.5	21.4	4.28	5.7	46.7	9.34
7.4	24.3	4.36	5.6	47.2	9.44
7.3	26.7	5.34	5.5	47.7	9.54
7.2	29.0	5.80	5.4	48.2	9.64
7.1	31.0	6.20	5.3	48.6	9.72
7.0	32.6	6.52	5.2	48.9	9.78
6.9	34.6	6.92	5.1	49.2	9.84
6.8	36.0	7.20	5.0	49.5	9.90
6.7	37.4	7.48	4.9	49.7	9.94
6.6	33.6	7.92	4.8	49.8	9.96
6.5	40.0	8.00	4.7	49.9	9.98
6.4	41.0	8.20	4.6	50.0	10.00
6.3	42.0	8.40	4.5	50.1	10.02

Next calculate the stock solution concentrations using a dilution factor of 1:200 for both macro and micronutrients. Then determine chemical compatibilities from table 13-14 and convert weight of nitric acid to volume (table 13-16). The completed worksheet should look like figure 13-7.

13.69 Safety, Chemical Quality, Quantity, and Storage

Those making up the stock solutions should be trained to handle the chemicals safely. Rubber boots, a rubber apron, rubber gauntlet gloves, and a face mask or goggles should be provided when nitric acid, sulfuric acid, or highly acid stock solutions are handled. It is prudent to wear this equipment even when the solutions are not highly acidic, because splashing can still damage clothes and sting in cuts. At no time should concentrated salt solutions be handled without eye protection.

The quality of chemical used should be the lowest possible pure enough to do the job. Fertilizer grade chemicals are good enough. Some of the micronutrient compounds may only be available in the higher grades, but these are needed in such small amounts that cost is not a problem.

The method for estimating the gross amount of irrigation water needed in greenhouses for trees is provided in section 4.15. This figure divided by the dilution factor can be used to estimate the amount of concentrated stock solution needed for each solution used, and this, in turn, can be converted to the amount of chemical needed for a season. This figure can be rounded up to the commercial units sold (i.e., 100-pound sacks, 30-gallon drums, etc.) for ordering purposes.

column

Line 1	2	3	4	5	6	7	8	9	10	11
	Nutrient Elements (ppm)							Total	Stock soln. x 200	Cpd. compat.
	(NO_3) N	(NH_4) N	P	K	S	Ca	Mg	Cpd mg/l		
1. Target Conc.	140	60	30	150	40	100	50			
2. Water anal.	0	0	0	5	16	160	29			
3. Net to Add	140	60	30	145	24	0	21	ppm	g/l	
Cpds. used:	–	–	–	–	–	–	–	–	–	–
4. HNO_3	133							601	120	A
5. KNO_3	52			145				376	75.2	A
6. $(NH_4)_2HPO_4$		27	30					128	25.6	A
7. $MgSO_4 \cdot 7H_2O$					28		21	216	43.2	A
8.										
9.										
10 Total										
	Fe	Cl	B	Mn	Zn	Cu	Mo		x 200	
11. Target Conc.	4	4	0.5	0.5	0.05	0.02	0.01			
12. Water anal.	0	3	0.1	0	0	0	0			
13. Net to Add	4	1	0.4	0.5	0.05	0.02	0.01	ppm	g/l	
14. Fe chelate	4							40	8	B
15. KCl		1						2.1	0.4	AB
16. H_3BO_3			0.4					2.2	0.4	AB
17. $MnSO_4 \cdot 4H_2O$				0.5				2.0	0.4	AB
18. $ZnSO_4$					0.05			0.12	0.025	AB
19. $CuSO_4 \cdot 5H_2O$						0.02		0.08	0.016	AB
20. $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$							0.01	0.02	0.004	AB

Figure 13-7.—Completed worksheet for calculation of fertilizer stock solutions at Mount Sopris.

All of these chemical compounds will store well if they are kept dry and cool.

13.7 Preparation of Nutrient Solutions from Commercial Mixes

The first steps are the same as for custom formulation:

1. Decide on target concentrations for each mineral nutrient.
2. Subtract from this the mineral concentrations already in the water supply. The difference is what needs to be added.
3. Select a target pH.
4. Using the titration table for the water supply, determine how much acid must be added to reach the desired pH.
5. Select the acid to be used. Subtract the concentration of nutrient added by the acid from line 3 of the worksheet. This leaves the nutrient to be supplied by the commercial mix. In the first example (section 13.6), if we used nitric acid to supply the 8.6 meq of acid needed that would be 542 mg/l nitric acid or 542 x 0.222 = 120 ppm N

   Subtract this from the total needed,

   223 − 120 = 103 ppm N yet to be added.
6. Select the commercial mix to be used based on the ratio of N, P, and K needed. However, commercial fertilizers generally express P as P_2O_5 and K as K_2O, so, requirements must be stated in the same terms. In example 1, we need 27 ppm P. Using table 13-8, we find the fraction of P in P_2O_5 and divide.

   (27) ÷ (0.437) = 62 ppm P_2O_5

   We need 155 ppm K, so by the same calculation we need

   (155) ÷ (0.830) = 187 parts per million K_2O

   The ratio of N: P_2O_5 : K_2O that we need is then 103:62:187. This is approximately 1⅔:1:3, and we look for a fertilizer mix with approximately that composition. We can come close if we select a "pot mum special" having an analysis of 15-10-30.

To calculate how much is needed in the nutrient solution, select one of the nutrients and divide by the percent present. If we use potassium as K_2O then,

(187) ÷ (0.30) = 623 mg/l of fertilizer mix.

This is multiplied by the dilution factor to obtain the concentration of the stock solution.

The manufacturer normally selects compounds that are compatible. Unless the nurseryman experiences problems with precipitation, he needn't worry about keeping everything in solution. Prepared fertilizers frequently do not show sulfur, calcium, and magnesium on the analysis. If these are not in the NPK fertilizer, they must be added separately, and that is where any precipitation problems will occur. Some fertilizers contain all required micronutrient elements as well. If they do not, these must also be added.

Micronutrient elements may either be included in the nutrient solutions as a soluble mix or may be mixed with the pot mix as a powdered glass frit. Fritted micronutrient elements are available in several formulations.

For tree seedlings, it is recommended that the ratio of elements be approximately that recommended by Hoagland and Arnon (1938) or Ingestad (1971).

13.8 Preparation of Nutrient Solutions the Easy Way

Read the instructions on the bag, follow them, and hope it works. Many fine seedlings are produced with very minimal knowledge of the mineral nutrients available to the tree, but the authors do not recommend operating this way. If anything goes wrong, it is much harder to find the cause and correct it.

13.9 How to use Nutrient Solutions

The amount and kind of nutrient solution needed will vary with the phases of the growing cycle. During germination, mineral nutrients are not needed, because they are supplied by the seed. At this point, maintaining a relatively sterile medium will help control damping-off fungi. During germination, the surface is kept moist by frequent light waterings. If a nutrient solution is used, this can result in salt buildup, because there would not be enough water put on for leaching. The water applied during germination should be acidified as needed, however.

Nutrients should be applied when the seed coat is shed. During the juvenile and exponential growth phases, nutrient solution should be applied in excess each time it is used. This insures that the entire rootball is wetted and any excess salts are flushed out. Frequency of irrigation is determined by season of year and size of the seedlings relative to the containers.

The nurseryman may fertilize at every watering or only occasionally. Each method has its merits. Occasional fertilization puts less wear on the injector, is less work, and generally consumes less fertilizer. Further, if the nurseryman has more stock solutions than he has injectors, he can inject one first and then another. However, he will not be certain of the nutrient environment to which the seedlings are exposed, nor will he have as good control of the pH. By fertilizing at every watering, the nurseryman provides the seedlings with a known, constant, and highly favorable pH and nutrient environment (McGuire 1972).

SECTION 14.—OTHER GROWTH FACTORS

14.1 Mycorrhizae

14.11 Effect on Seedlings

14.12 Which Mycorrhizal Fungus Is Best?

14.13 Inoculating Seedlings

14.2 Carbon Dioxide (CO_2)

14.21 Why Plants Need CO_2

14.22 Growth Response to CO_2 Enrichment

14.23 Providing Added CO_2

SECTION 14.—OTHER GROWTH FACTORS

14.1 Mycorrhizae

Certain fungi have the ability to invade plant root tips and live within them to the mutual benefit of the fungus and the plant (Zak 1975, Marx and Barnett 1974, Hacskaylo 1972). Ectomycorrhizae are most common on conifers. Their presence is indicated by the color and shape of small side roots characteristic of the particular fungus, and confirmed by the presence of a Hartig net visible under a microscope. Fungal hyphae extend from within the roots out into the soil.

14.11 Effects on Seedlings

Mycorrhizal fungi are pathogen antagonists. They help prevent damping off and root rot. These fungi also assist in mineral uptake and possibly water uptake, probably by increasing the effective absorbing area. Perfectly good non-mycorrhizal seedlings can be grown in the greenhouse, because conditions are controlled to minimize stresses of all kinds. Even so, mycorrhizal seedlings will frequently be healthier and more robust than nonmycorrhizal ones, and if anything goes wrong, the non-mycorrhizal seedlings will suffer much more quickly. In particular, non-mycorrhizal seedlings are subject to root rots caused by a poorly aerated pot mix plus overwatering or excessive humidity.

14.12 Which Mycorrhizal Fungus Is Best?

Many fungi will form mycorrhizae with a variety of tree species, and within both species of fungi and species of trees there are genetic differences in the ability to form a union (Trappe 1969). The question is which isolate of which fungus will best adapt this particular seedling to the site on which it is to be planted? Research to answer that is just beginning.

The procedure is to isolate a fungus that is known to form mycorrhizae with the tree species of interest. The fungus is propagated in pure culture and introduced into sterilized pot mix either as spores or mycelium. Seedlings are grown in the inoculated medium, and their roots are examined to see if and to what extent they become mycorrhizal. The seedlings are then outplanted either in the field or in a controlled environment where they can be subjected to simulated field site stresses. After a suitable period, the seedlings are examined for survival and vigor, and differences between groups of seedlings with different mycorrhizal fungi or no fungi are noted. Marx and Barnett (1974) have isolated a strain of *Pisolithus tinctorius* which forms profuse mycorrhizae on a variety of species, and has been shown to be very beneficial to southern pines. It has enabled slash pine to thrive on mine spoils with a pH of 3.5. It is being widely tested and may be commercially available in a few years.

Riffle and Tinus[1] have found a *Suillus* strain which is highly beneficial for ponderosa and Scotch pine planted in North Dakota.

14.13 Inoculating Seedlings

In humid regions, such as the Southeast and the Pacific Northwest, seedlings in greenhouses may become mycorrhizal by windborne inoculation. If so, no effort to inoculate them is needed. Even if the seedlings are non-mycorrhizal when they go to the field in these regions, they usually become inoculated quickly because of the presence of the fungi at the site.

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[1] *Unpublished data by J. W. Riffle and R. W. Tinus, Rocky Mountain Forest and Range Experiment Station, Lincoln Neb., and Bottineau, N. Dak., respectively.*

In drier climates, however, inoculation is not automatic either in the greenhouse or in the field. In the Plains, appropriate fungi may not be present at the planting site. In these situations, it is important that the nurseryman inoculate his seedlings deliberately. The following methods are available:

1. The most readily available and reliable method is to incorporate 2-3% by volume of forest duff into the pot mix. The duff is best collected fresh from under a stand of trees of the species to be grown. If that is not feasible, collect it from under a stand of trees closely related by both species and native site. For instance, duff from under a ponderosa pine stand will probably be equally good for inoculating lodgepole and white pine, and even larch and spruce. Rake aside the undecomposed litter and pick up the humus or top inch of mineral soil with a flat shovel. Screen out particles that are too large to mix well with the rest of the pot mix. Keep the inoculum moist until used. In small quantities, it is convenient to store it in burlap sacks lined with plastic garbage bags. For large quantities, line a bin with polyethylene, fill with inoculum, and cover tightly with polyethylene. When the pot medium is mixed, add 2-3% by volume of the inoculum.

   Although duff inoculum works well, using it risks adding harmful organisms. This risk may be assessed by collecting some inoculum well in advance of the need to use it. Fill a few containers and seed them to the species to be grown. Watch them carefully for several months for signs of damping off, root rot, nematodes, or harmful insects. If the trees grow normally and no problems develop, use the inoculum in the production run. If problems with insects or nematodes develop, treat the inoculum with an appropriate pesticide before use. If pathogenic fungi are the problem, try a different source of inoculum.
2. Allow mycorrhizal fungi to fruit in the greenhouse. Some fungi, such as *Thelaphora terrestris,* will fruit readily, while others will not. Conditions in the greenhouse may not be right for fruiting, except at certain times. This method of inoculation is much less certain than using duff, and it severely restricts the variety of fungi that will inoculate the seedlings. Its advantage is that it does not introduce anything harmful into the pot mix.
3. Incorporate a pure culture of the desired fungus into the pot mix before seeding. This is not a viable option at present, because pure cultures are not available in quantity yet. When they are, this will become the recommended procedure.

14.2 Carbon Dioxide (CO_2)

14.21 Why Plants Need CO_2

In the atmosphere, there are about 325 ppm CO_2. This small concentration is the source of carbon for all land plants. Plants take up CO_2 during photosynthesis and give it off through respiration. In the light, photosynthesis is usually greater than respiration, which results in a net uptake of CO_2, but under conditions of high temperature or reduced CO_2 concentration, it may not be. When photosynthesis equals respiration (equals the compensation point), the plant can maintain itself in the light, but it does not grow. This occurs frequently on bright days in closed greenhouses (Tinus 1972).

14.22 Growth Response to CO_2 Enrichment

The strategy for producing large seedlings in a hurry is to optimize all growing conditions possible. When CO_2 becomes limited, growth slows down and may even cease. CO_2 must be added to the atmosphere to at least bring it back up to normal concentrations.

Almost all woody plants that the greenhouse nurseryman is likely to grow exhibit "photorespiration." This is a loss of CO_2 which occurs only in the light. Its function is not well understood, but it appears that plants can do without it. Photorespiration is suppressed by high concentrations of CO_2, and net photosynthesis increases accordingly. High CO_2 also increases the diffusion gradient from the outside air to the chloroplast where it is consumed. However, high CO_2 tends to close the stomata which decreases the amount entering the leaf (Tinus 1974c). Extremely high concentrations can be toxic.

The CO_2 concentrations most often used in greenhouses are 800-1,500 ppm, which represents a good compromise between increased CO_2 gradient and depressed photorespiration and closure of the stomata. In growth chamber experiments, where these concentrations have been maintained through the day, dry weight growth of seedlings has been increased 50-100% (Tinus 1972, 1976).

In a greenhouse, the response is likely to be somewhat less, because on warm days it will be necessary to ventilate to maintain proper temperature. Unless huge quantities of CO_2 are available, it will be impossible to maintain CO_2 levels much above that of the outside air. The growth response expected will depend on how much of the time the vents remain closed. During the winter, this may be all day, but during midsummer, it is usually possible to raise the CO_2 level for only a few hours in the early morning and again in the evening. The loss may not be as great as it sounds, however, because plant stomata commonly close during midday because of water stress, even when the plants are well watered. Thus, photosynthesis is normally most rapid in the early morning with a secondary peak in the evening.

14.23 Providing Added CO_2

One method used some years ago was to pile fresh manure in the greenhouse. Decomposition released CO_2, and the remains were added to the pot mix after composting was complete. This method has fallen into disfavor, because it takes up valuable space, and release of other gases degrades the working environment.

Release of CO_2 from a tank is a more suitable method. This is costly, however, and is generally reserved for growth chamber use.

Scrubbed stack gas from industrial or electric generating plants can be used, if available. This would be practical if the greenhouse is located close enough so that it could use the waste heat produced. If available at all, stack gas would probably be available in sufficient quantity so that elevated CO_2 levels could probably be maintained even when the vents were open.

The most common method is combustion of propane or natural gas. There are burners designed specially for CO_2 generation available from nursery supply houses. Actually, any burner will do, provided it burns with a blue, non-turbulent flame. If the flame is yellow, there may be harmful products of partial combustion given off, particularly carbon monoxide and ethylene. Carbon monoxide is probably more dangerous to humans than to plants, but ethylene is a potent plant hormone that promotes dormancy and leaf absicission among other things. If the flame is short and very turbulent, there is likely to be some gas that escapes unburned into the greenhouse.

For a glass or fiberglass greenhouse of average tightness, it takes about 2.5 BTU per hour of gas per cubic foot (22 Kcal per m^3) of greenhouse to maintain 1,000 ppm CO_2 in the atmosphere. For polyethylene covered or tight houses of other construction, gas consumption can be reduced somewhat.

Propane is fairly standard in composition and can be relied upon to be low enough in sulfur so as not to damage plants. Natural gas varies in composition, and its sulfur content should be checked. For safe use, the carbon to sulfur ratio must be 10,000 to 1 or greater.

The burner is conveniently controlled by a timeclock in series with the open-on-rise side of the thermostat that controls the first stage of cooling. The timeclock turns the burner on during daylight hours, and the thermostat turns it off when the vents open and the fans come on.

CO_2 concentration is regulated by the size of the flame on the burner. Once the correct setting has been found, it is not necessary to monitor CO_2 levels continuously. An occasional spot check is enough. CO_2 testers with sufficient accuracy are available for less than $100. If the nurseryman is located near a university or agricultural research station, he can probably arrange for analysis of air samples on an infrared gas analyzer. Samples can be taken by filling an inner tube with greenhouse air with a bicycle pump. Butyl rubber is highly impermeable to CO_2, and such samples should be good for days. Do not use plastic bags, unless the samples can be analyzed in a matter of minutes. Be sure no human breath is mixed with the sample taken.

SECTION 15.—GROWING SCHEDULE FORMULATION

15.1 Definition of Growing Schedules

15.2 Growing Schedule Format

15.21 How to Read a Growing Schedule
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15.4 Testing and Adjustment of the Growing Schedule

15.5 Examples of Growing Schedule Development

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15.54 Other Examples of Growing Schedules

SECTION 15.—GROWING SCHEDULE FORMULATION

15.1 Definition of Growing Schedules

A "greenhouse rotation" is a program for space utilization in the shadehouse and greenhouse throughout the year. It is planned to insure that there will be a place to put the containers and seedlings when they need to be moved from the greenhouse to the shadehouse or when a new crop is to be started in the greenhouse. The greenhouse rotation must be planned during design of the facility so that necessary space will be available (section 5.3). It is useful to keep a written record of the planned rotation and what actually happened, so that if errors are made, they will not be repeated.

A "growing schedule" is a chart of environments to be maintained and operations to be done as a function of calendar date from seed preparation to shipment from the nursery. It incorporates much of what is known about how to grow a particular crop and have it in proper physiological condition on the required shipping date. Some thought must be given to the growing schedule during facility design to insure that the greenhouse will be able to maintain the required conditions. The growing schedule also specifies the time needed to grow the crop under a given environment. This is crucial to planning the greenhouse rotation. A detailed record of conditions maintained and growth progress should be kept so that errors in the original growing schedule can be corrected.

15.2 Growing Schedule Format

15.21 How to Read a Growing Schedule

Figure 15-1 is an example of a growing schedule. Time is on the horizontal axis at the top. This particular crop has a 1-year rotation. The factors to be controlled and operations to be performed are listed on the vertical axis at the left. The body of the schedule specifies the level or condition of each environmental factor and the time at which that takes place. This figure summarizes everything we know about how to grow that size of white spruce at Palmer, Alaska, for spring outplanting. Refer to it throughout the following discussion.

Species White spruce **Container** 10 cubic inches **Outplanting** Spring **Location** Palmer, Alaska **Cycle** Summer (1/yr.) Info. Grade

Source Fairbanks, Alaska

Season		MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
Growth stage		Sow Germination	Juvenile growth		Exponential growth			Natural hardening					Maintain dormancy	
Day temp (°F)	**Optimum**	70	72		72			65 (declining with the season)						
	Permissible	65-75	68-75		68-75			55-70						
Night temp (°F)	**Optimum**	70	61		61			55						
	Permissible	65-75	56-72		56-72			50-70						
Rel. Hum. (%)	**Optimum**	80		60										
	Permissible	60-90		50-70										
Daylight				75% Sunlight (unshaded 2 layer ghs)				50% Sunlight (shadehouse)						
Supplemental light			8 watts/ft^2 incandescent light at least 6% of the dark period. No dark period over 15 min					None						
Water		Frequent, light surface always wet		As needed with nutrient solution Surface should dry Rootball always near field capacity			Leach with water Dry to wilting	As needed Treat as before						
Fertilizer		None	Complete, high N pH 5.5-6.0 EC 1,500-2,000 μmhos Water in excess each time Rinse foliage with water				None	Complete, low N, high PK Otherwise, as before						
CO_2 level		Normal atmos	1,000-1,500 ppm whenever vents are closed during daylight hours					None (Normal atmosphere)						
Operations		Fill, seed, load ghs	Thin				Move trees to shade-house							Ship May 1

From left to right, is a time line. Points along this line are designated as growth stages of the crop or points at which certain management activities take place. From top to bottom, at the left of the sheet, are environmental parameters (temperature, humidity, light, water, fertilizer, CO_2) and operations to be controlled. In the body of the schedule, below the time line and to the right of the parameters itemized, is a statement of the condition or setting and the permissible limits of parameter at that point in time. When reading the growing schedule, one is really scanning the condition of the environment in which the plant is growing at any given time. By reading the time line and correlating the graduated distance along it between management activities indicated, the length of the various growth stages (germination, juvenile, elongation, caliper growth, and dormancy) can be seen.

There are other formats that can be used to set up growing schedules. How it is done is not important as long as they pròvide the grower with an adequately detailed plan of action while the crop is in the nursery. The growing schedule must be flexible, of course. Disease and equipment problems can occur to slow the growth. In semicontrolled greenhouses, weather can also have a significant influence.

15.22 Common Features

All growing schedules should have these attributes:

1. They should define the dates between which the crop will be in the greenhouse, the crop conditions at any time during the growth cycle, targets for height, caliper, and other indicators of growth stage, and the condition of the environment in the greenhouse at any given time during the growth cycle.
2. Generally, the location of the crop in the greenhouse and specific benches to be used are not part of the schedule. These items belong in the greenhouse rotation plan.
3. The environmental control designated in the growing schedule should be based on the best biological information available for that particular species. The full capability of the greenhouse environmental modification system should be used to meet these growth optimization guides.
4. The growing schedule should show the complete cycle from seed to crop maturity, even if the crop is moved to a shadehouse partway through its schedule.
5. The length of each segment of the growing schedule and the calendar dates it covers should be defined. This is valuable not only for reference while the crop is being reared, but also to record the true length of time needed to produce a satisfactory crop. Records of the length of time and cultural modifications necessary to rear good crops of trees are valuable for more precise growing schedule formulation for future crops.

15.23 Relation of the Schedule to the Rate of Crop Development and Condition

Stages of hardening.—The species and required size determines the container size and the time required to grow it. The site on which it is planted and the time of year determine the physiological condition of the tree when it leaves the nursery.

Start with the date the end product must be ready to ship, and work backward in time. After the seedlings have reached the desired size, they may need hardening. There are three distinct stages of hardening.

Fully hardened seedlings are dormant with well developed winter buds. They have reached a high degree of cold hardiness, and the chilling requirements for bud break have either been met or will be by the time warm weather arrives at the planting site. This condition requires 6 to 10 weeks to achieve and is generally needed for spring, fall, or winter planting. The seedling can be expected to put on a large flush of top growth the first season in the field.

Dormant seedlings have set bud, and all of the stem tissue has lignified, but they are not cold hardy. This degree of hardening takes 3 to 5 weeks to produce and is sufficient for planting in summer or early fall when frosts are not expected. Normally, there will be no top flush until the following year.

Succulent seedlings have had no hardening. Their top growth is very active, and the upper part of the stem is not lignified. They are as tender as lettuce and are usable only in the most favorable weather on the best sites (i.e., where site conditions are not very different from greenhouse conditions). When used judiciously, these seedlings will continue growth without interruption, and no time for hardening needs to be allotted in the growing schedule.

Stages of growth.—At the date when the seedlings must be full height and ready for hardening or shipment, they will have passed through three growth stages.

Germination begins when the seed is placed in warm, moist pot mix; it should be complete in 10 to 14 days. If it is not, either the seed has not been properly prepared, or the seed is poor. Prompt and complete germination in the greenhouse nursery is important. Any delay is costly. The germination stage generally requires more frequent watering, no fertilization, less light intensity, lower temperatures, and more vigilance against disease than later in the life of the seedling.

Juvenile growth begins when the seed is exhausted and the tree becomes autotrophic. There frequently appears to be a pause in growth as the seedling forms a rosette above the cotyledons. The first green leaves are frequently different in shape, size, and ontogeny from the ones on a mature plant. No buds are visible. The seedling grows continuously. Less frequent watering than during germination is desirable so that the pot surface will dry. This helps control damping off. Light intensity may be the same or somewhat higher than during germination, but the seedlings must have sunlight, whereas, during germination, they may or may not need it. At this time, the temperature may be increased somewhat. CO_2 in the greenhouse atmosphere should be elevated, lights for the photoperiod control turned on, and fertilization begun. The length of this stage varies with the species and seed source anywhere from a few days to several weeks.

Exponential growth occurs after the seedling has fully taken hold and frequently begins to resemble a mature tree morphologically. The length of this stage is determined by how close growing conditions are to optimum, how large a tree is desired, and how soon one or more factors becomes limiting.

To know the time required for each of these growth stages, assume that the nurseryman has growth curves and a table of optimum conditions for the species he is growing. Moving backward in time through these three growth stages establishes the seeding date.

Next, allow time for seed preparation. Does it require stratification, water soaking, or other time consuming treatment? Finally, consider seed collection and proper storage, which brings us to the beginning of the growing cycle.

15.24 Timing

Given the date at which the product is needed, and once it is known how rapidly the seedlings will grow and how rapidly they can be put through the required stages, it is easy to establish the dates at which each stage must begin. These dates may need to be adjusted to allow one crop cycle to mesh with the next, and to coordinate the use of space and manpower. If the trees will remain in the greenhouse from sowing until shipment, the only requirement is that they be shipped in time to start the next crop. If shipment is delayed, the seedlings may need to be moved to a temporary holding area or cold storage. If the trees are to be moved to a shadehouse for part of their residence at the nursery, they must be able to tolerate conditions there. If the trees are fully hardened, they can be moved to the shadehouse at any time.

Species and ecotypes differ greatly in their ability to tolerate freezing. Many West Coast ecotypes must be protected by insulation and heat so that their roots do not freeze at all. Ecotypes of the interior West can generally be frozen without root damage after they are properly hardened. Roots do not harden to the degree the tops do, however, and must be maintained above their killing temperature. (For list of known root killing temperatures see Havis 1976). Rootballs of conifers should not remain frozen for more than a few days at a time, unless the tops are treated with antitranspirants, covered with polyethylene, or mulched with snow. This is because, even though the roots may not be damaged, the trees will be unable to take up water and the foliage may be desiccated and damaged. If seedlings are dormant but not hardened, they may be moved to the shadehouse during mild weather. Many West Coast ecotypes cannot tolerate frost at this stage, but in the interior West depending on the species and seed source, light frosts should not hurt, but the seedlings should not be subjected to temperatures lower than 27° F (−3° C) before they have had a chance to harden. In the interior West, if the trees are succulent, they must have at least 3 weeks of frost free conditions before being subjected to low temperatures. Further, they should be protected from intense sunlight, strong winds, and very dry air. For each location, the nurseryman must determine from weather records what his limiting dates are for transferring plant material out of the greenhouse.

In addition to the climate, the nurseryman must consider how the proposed timing will mesh with starting the next crop. Generally, each crop will start and end about the same time each year. Thus, there will be one, two, or three crops per year, but not 1½ or 2½. A crop must be moved out of the greenhouse before the next one is started; but the shadehouse or other storage area may accumulate more than one crop at a time. Space must be allowed, if crops are expected to overlap.

15.25 Facilities Available

The sequence of growth stages outlined in section 15.23 will be the same regardless of the quality of the facilities in which the trees are grown, but the time required will depend on how closely conditions can be optimized. Several situations apply:

1. The greenhouse may be fully controlled, or it may have a lesser degree of control. How much that lengthens the required growing time depends on the species, the climate, and time of year.
2. The crop may be grown in the greenhouse for only part of the growing cycle and finished off in a shadehouse.
3. Time of year is important, because it affects the amount of sunlight available. Winter crops without supplemental high intensity light for

photosynthesis always take longer to grow than summer crops.

4. Climate is important, because there may be seasons of cloudy or foggy weather which affect light intensity, and depending on how mild or harsh the climate is, cost of seedling production may vary greatly with season.

15.26 Growing Data Needed

For many species desirable conditions for each stage of growth are known. These are listed by species in sections on temperature, light, watering, humidity, mineral nutrition, and other factors. However, good information on rate of growth is available for relatively few species, especially as related to the interaction between the various environmental factors. In the previous sections, when optimum conditions for one factor are described, it is assumed that all other conditions for growth are also favorable, if not optimum.

15.3 Growing Schedule Assembly

To show how growing schedules are constructed, a step by step procedure and three examples are provided.

15.31 General Procedures and Rules of Thumb

1. Select species, size of seedling, time of outplanting, location of planting, location of nursery.
2. Determine dates for all growth stages from the shipping date or other fixed time, using what is known about the time required for each stage. This will depend on species, seed source, size of container, time of year, location, and capabilities of the greenhouse.
3. Select environmental conditions to be maintained during each growth stage.

15.32 Sowing

During sowing, conditions can be whatever is comfortable for people to work in. If it takes more than a day or two to fill a greenhouse, germination uniformity can be increased by keeping the temperature just above freezing until it is full. Then warm it up and allow germination to occur.

15.33 Germination

A temperature of 70° F (21° C) is good for many species' germination. It is warm enough for prompt germination, although germination is usually faster at higher temperatures. However, at higher temperatures, it is harder to keep the germinating seed from drying out, and the seedlings tend to be spindly because of excessive hypocotyl elongation. Note that best greenhouse germination temperatures are not necessarily the same as those used in standard germination tests (Schopmeyer 1974).

Relative humidity should be high enough so that the seed will not dry out and the young seedling is not under high transpiration stress. Seventy percent is a good target figure, which is also low enough so that the danger of disease is not increased.

Light intensity is frequently lowered during germination, because young seedlings can be damaged by very intense light. How necessary this is depends on the species, the location, and the time of year. Shading is not necessary during long periods of cloudy weather and is rarely necessary during the fall and winter. Shading is frequently necessary during spring and summer both to avoid excessive light intensity and to avoid excessive day temperature.

If supplemental light is needed, it should be applied to lengthen the photoperiod soon after germination. How critical this is depends on the sensitivity of the particular species and seed source. For instance, high latitude (54° N and above) origins of white spruce are very sensitive to short photoperiod and are capable of setting bud in the cotyledon stage. Early budset would be a disaster, because the bud would require many weeks of chilling to break, and that would completely upset the growing schedule. However, Engelmann spruce from New Mexico does not seem to be sensitive to photoperiod, although supplemental light should probably be applied as insurance.

Watering should be frequent and light so that the pot surface does not dry. Small seeded species especially will be on or very close to the surface.

During germination, the seedling receives mineral nutrients from the seed. By not fertilizing until after the seed coats have dropped, the chance of damping off is reduced.

There is no point in providing a high CO_2 atmosphere until there is enough photosynthetic tissue to absorb it.

15.34 Juvenile Stage

After the seed is used up and the radicle is well down into the pot, conditions should be changed. Temperature should be set at the optimum for the species (table 10-1).

Humidity should be reduced somewhat to about 60% ±10 to insure that liquid water does not stand on the foliage for any length of time. The seedling has now established root contact with the pot mix and can tolerate a little more transpiration stress in the interest of avoiding foliage disease and root rot.

Likewise, it is no longer desirable to keep the surface wet. The frequent light waterings are discontinued, and the surface is allowed to dry between waterings. From this point on, each watering will contain nutrient solution formulated high in N to maximize growth rate. The rootball will be kept near field capacity, unless this causes insufficient aeration. Each watering will be in excess so that the rootball will be recharged with nutrients, but no unused salts will be allowed to accumulate. The final few minutes of each watering will be with plain water to rinse the foliage. This will prevent algae growth and salt burn.

As the seedlings get older, they can generally use more light, especially after the crowns close. Spring crops will get more sunlight automatically as the days lengthen and the sun angle increases. Late summer or fall crops may need to have shade removed to achieve this effect. The CO_2 level should be elevated to about 1,000 ppm during daylight hours, whenever the vents are closed.

15.35 Exponential Growth

Many species show no sharp transition between the juvenile and exponential growth stages. The conditions required for both stages are essentially the same, but they will change somewhat, because the season is changing. The warm days of summer may make it difficult to keep day temperatures down to the optimum, and there will be less time that CO_2 can be elevated, because the vents will be open more. Frequency of watering will increase because of the warm weather and increasing size of seedlings.

The exponential growth stage continues until the seedlings are as tall as desired. At this point, seedlings will be tall but quite slender with rather few, if any, short side branches. The foliage will be soft and limber, and the upper part of the stem will be green and unlignified. Few, if any, of the seedlings will have a visible terminal bud. Since growth during this state is exponential, a small change in growing time may make a large difference in the size of trees produced. If they grow faster than expected, the exponential phase can be terminated sooner. If they grow slower than expected, a decision must be made as to whether to accept smaller trees or to continue to grow them longer. If the trees are to remain in the greenhouse during hardening, can the entire hardening period be shifted later in time? If that will interfere with the planting of the next crop, or if the season of the year is changed so that hardening is difficult or impossible, the answer is probably no. If there is a slack time in the schedule, the answer is probably yes.

If the trees are to be moved to a shadehouse for hardening, they must leave the greenhouse during frost free weather and not be frosted for at least several weeks after they go out. This places a cutoff date on any movement out of the greenhouse somewhere in the late summer or fall, depending on location. If extending the growing time will move the transfer beyond the cutoff date, then smaller seedlings must be accepted, or they must be hardened in the greenhouse.

15.36 Bud Development and Stem Lignification

Spring planting requires a tree that is able to put on a good flush of top growth after outplanting. In many species, such as spruce, the cells that make up that flush are laid down in the buds formed at the end of the previous season. A good flush is directly related to good bud development. Thus, conditions must be right and sufficient time allowed for adequate bud development.

Bud development is initiated by changing the growing conditions and subjecting the seedlings to a moisture and nutrient shock. When the seedlings are moved to the shadehouse during the summer, the day temperature probably becomes warmer than optimum and the night temperature cooler than optimum. Both decline as the season advances into fall. Relative humidity drops and becomes much more variable. Shading in a shadehouse is usually 40-50% which is somewhat lower light intensity than in an unshaded greenhouse. There will be no supplemental light in the shadehouse, a key variable in the control of dormancy. In fact, be sure that the darkness is not interrupted by nearby street lights or by work lights inside. Shade alone may or may not hasten dormancy, and Hahn[1] reports that shade promotes more height elongation of coastal Douglas-fir.

Upon transfer to the shadehouse, the seedlings are watered heavily with plain water to remove nitrogen, and then they are allowed to dry to the wilting point. This process, which will be termed "drought stressing," must be done with care so that the seedlings are not permanently damaged. Because drying will not be completely uniform, it may be necessary to water a portion of the crop by hand so that damage is prevented, but the rest of the crop can continue to be stressed. As soon as the growing medium reaches the wilting point, the crop is then rewatered with a low N, high PK solution.

Drought stress is an effective way to stop height growth quickly, especially when used in conjunction with a shortened photoperiod. Reduction of nitrogen and increasing phosphorus and potassium in the nutrient solution is a widely used practice that seems to produce good seedlings, but the evidence that it is necessary is not very strong (Christersson 1973, Hulten 1976, Kelly 1971, Timmis and Tanaka 1976, Tanaka and Timmis 1974, Tmmis 1974).

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[1] *Personal communication with Phillip Hahn, Georgia-Pacific Corp., Eugene, Oreg., May 1978.*

15.37 Cold Hardening

After the buds have developed sufficiently, the stem is completely lignified, and caliper growth is sufficient, then low temperature and short photoperiod may be used to develop cold hardiness. When stock is overwintered in a shadehouse, this happens naturally, and the nurseryman has only to keep the stock watered when temperatures are above freezing, and adequately mulched to prevent the roots from becoming too cold. Roots never develop as much cold hardiness as do the shoots, but with good thermal contact between the container and the ground and with adequate mulching for insulation, the seedlings will overwinter in good shape. Hardening in the fall is fairly easy to accomplish in the interior West, but is much more difficult on the West Coast.

In climates with warm but rainy winters, it may be necessary to overwinter the seedlings in a structure with a solid roof to shield them from excessive moisture. Continuously saturated rootballs mean poor root aeration, which encourages root rot.

One important function of cold temperature is to remove the inhibitors in the plant that hold the buds dormant. The length of time required to meet the "chilling requirements" also varies with species and seed source. For most species, the minimum requirements are unknown, but 5 weeks is enough for many species. Only a few require longer periods, such as green ash which requires 8 weeks, and coastal Douglas-fir which requires 8-12 weeks. If the chilling requirements have not been met, the buds will not break and grow promptly, if at all. For many species of spruce and fir, the terminal remains dormant, but the lateral buds grow. Lack of height growth after outplanting is a common problem of winter grown seedlings which are shipped in the spring or early summer without cold hardening.

15.4 Testing and Adjustment of the Growing Schedule

After a growing schedule has been formulated, plans can be made for the operations needed to grow the crop. Supplies can be ordered and a crew hired, so that they will be available when they are needed. Space can be allocated and transportation arranged. If any of these factors do not fit or are not feasible because of poor timing, competition for available space, or other problems, the growing schedule may need to be revised.

Progress of the crop should be monitored continually, and any discrepancies between expected and observed performance should be carefully noted. If the nurseryman is inexperienced at running a greenhouse container operation, or if this is his first crop of a particular species, it is likely that the crop will not grow exactly according to the growing schedule. This will make it necessary to change the timing of growth stages and operations from what was originally planned. The nurseryman should note carefully what happened to make the change necessary so that the growing schedule for the next crop cycle will be more accurate. There also will be year to year variations in weather and management decisions that will make it necessary to continually fine tune the growing schedule.

15.5 Examples of Growing Schedule Development

The following specific examples are intended to help the reader follow the procedure and reasoning behind the development of growing schedules so that he can generate his own.

15.51 White Spruce for Interior Alaska

Following the procedure outlined in section 15.3, suppose we want sturdy white spruce with an 8- to 12-inch (20- to 30- cm) top for late spring planting in the interior of Alaska. The nursery will be at Palmer, Alaska. That information fixes the first set of variables. At that latitude, the best cropping cycle will be one per year, with the exponential phase of growth centered on the longest days of summer. We only want a medium sized tree, so, there should be plenty of flexibility in timing. Plan for delivery of fully hardened stock about May 1.

Container size should be 8-15 cubic inches (139-250 cm^3) for a spruce with a 10-inch (25-cm) top. Since there will be plenty of time but a very cold winter, the most economical strategy will be to transfer the fully grown seedlings to a shadehouse in late August and let them go dormant and harden naturally. The greenhouse can then be shut down in winter.

Since the seedlings will be overwintered in a shadehouse, they can be shipped almost any time, so that is not a fixed date. However, they must be moved to the shadehouse at least 3 weeks before frost, and preferably 5 weeks. At Palmer, Alaska, that sets the date for moving the seedlings to the shadehouse at August 15. To reach the desired size, it will take about 20 weeks from seed in a fully controlled greenhouse. That means germination must begin March 15. Seed stratification, if required, must be complete by March 7, which allows 1 week for filling and sowing.

The reader should examine figure 15-1 and follow down the column of environmental conditions for each growth stage as we proceed through them.

Germination.—Conditions for seed germination are determined by the requirements of the species and seed lot, not by the location of the nursery. White spruce from interior Alaska apparently requires no stratification, and there is nothing unusual about temperature requirements. In this example, we sow dry, unstratified seed, with temperatures, humidity, watering, fertilizer, and CO_2 as described in section 15.3.

In March, at Palmer, Alaska, light intensity inside an unshaded greenhouse is not likely to be excessive, or should shading be necessary to avoid excessive day temperatures. Therefore, use no shading.

Supplemental light should be applied as soon as germination begins, because white spruce from high latitudes is very sensitive to short photoperiod and is capable of setting bud in the cotyledon stage.

Juvenile and exponential stages.—Spruce shows little distinction between a juvenile and exponential growth stage in the greenhouse nursery, and the requirements of the seedlings are almost the same for both. As they get older, the seedlings can tolerate more intense light, which they will receive automatically as the season advances. Likewise, as the seedlings develop some bark thickness and especially after the crowns close, they can tolerate more heat. However, the spruce will not grow rapidly at high temperature.

Note (fig. 15-1) that the recommended temperatures are quite low. As the season advances, it will be harder to hold greenhouse temperatures down to what is specified. Shading may be needed.

Seedlings should reach 10 inches (25 cm) in height within 18 weeks after germination. If they grow faster than expected, the exponential growth phase can be terminated sooner. If they grow slower than expected, we will have to settle for a smaller tree, because we cannot move succulent seedlings to the shadehouse and have them go dormant and harden properly, if we wait much beyond August 15. An alternative would be to overwinter the seedlings in the greenhouse. This would give more growing time, but would also be more expensive. The decision has to be made about August 15.

If time were found to be too short on the first crop, the schedule could be modified on the second crop to start a few weeks sooner. In Alaska, there is a limit to how much sooner, because there is so little sunlight in winter. Another possibility is to improve cultural practices so that the second crop grows faster than the first. This is common because no book of instructions or list of recommendations can completely replace actual experience.

Hardening.—Assuming everything goes right and the full-sized crop is moved to the shadehouse on schedule, the environment will change. The atmosphere will no longer be high in CO_2. The daylength will be shortened, because there will be no supplemental light at night. The photoperiod will still be on the order of 16 hours, but that is short enough to permit dormancy of high latitude white spruce. The humidity will generally be lower outside than in the greenhouse. The temperature initially will probably be in the same range as in the greenhouse during the day, but cooler at night. Both temperature and humidity will be more variable.

The nurseryman now needs to be concerned with only four factors: water, fertilizer, mulch, and protection from animals. To initiate hardening, the seedlings are watered heavily to remove nitrogen and subjected to moisture stress. This must be done carefully, and errors on the wet side are preferable. After most of the succulent shoot tips have visibly wilted, but before any of them are irreversibly damaged, the seedlings are rewatered with a nutrient solution containing about 10% as much N and 50-100% more P than before. The seedlings are watered with this formulation whenever watering is needed as long as the rootball is not frozen.

When the seedlings are moved to the shadehouse, they should be up on racks with adequate ventilation under the pallets for air pruning. They should be kept that way until rootball temperatures become cold enough to stop root growth (about 36° F) (2° C). Ideally, the container bottoms should then be placed flat on the ground for good thermal contact, but if this would involve too much handling, they can be left where they are. About the time the rootballs become frozen, the seedlings should be mulched with sawdust, shredded peat, straw, or something similar. The mulch must cover the sides of the container and a loose covering over the top. If the seedlings are left up on racks, this will require a great deal more mulch than if they are flat on the ground. The covering over the top must not be put on until the trees are thoroughly dormant, which they should be if the rootballs are freezing. If there is any danger that rodents may live in the mulched seedlings overwinter, scatter poison bait on the surface of the containers before mulching. Ideally, the tops should be covered with snow soon after the rootballs freeze, but other waterproof coverings or heavy shade are acceptable.

Snow mold is not likely to be a problem in Alaska, but if it is encountered, the seedlings can be sprayed with a suitable fungicide such as Captan® before mulching.

If warm spring weather comes before it is time to ship the seedlings, the mulch should be removed and the seedlings placed back on racks with enough ventilation for air pruning of root growth. Just prior to shipment, they should be watered thoroughly with high N nutrient solution.

15.52 Bur Oak for North Dakota

In this example, we want large (20-25 cm) sturdy stock in large containers for spring planting in the northern Great Plains. Under optimum conditions, oak is fast growing, so, we can plan for two crops per year. However, oak requires high temperature for rapid growth, so, the most economical approach is to grow both crops during the spring and summer. This will be possible by starting early and hardening the first crop in a shadehouse and the second crop in the greenhouse (Appendix 2).

Bur oak is also a good example of a species requiring special seed handling. With most species, multiple seeding can compensate for low or slow germination. However, this is impractical with large seeded species such as walnut, pecan, or oak, because only one seed per cavity will fit. Acorns have a short storage life compared to many species. They cannot be allowed to dry out, and they cannot be frozen. Bur oak from North Dakota is unusual in that it is one of the few white oaks that requires stratification. The acorns are frequently infested with weevils, although they appear to have little effect on viability if the following collection and storage guidelines are followed (Tinus 1977a):

1. Collect the seed from the ground or shake the tree, but do not pick green seeds. This insures adequate ripeness and is also the easiest way to collect the seed.
2. Immediately float test the seed in water. Anything that sinks will germinate 80-90%, and anything that floats will germinate 0-30%. This eliminates seeds which have been damaged by drying or weevils, and it stops the drying.
3. Place the wet acorns in a plastic bag. Store them in a cooler just above freezing, but do not freeze them. This will provide the right moisture and temperature for storage and stratification.
4. When it is time to plant, bring the acorns into a warm room for a few days in advance and allow them to sprout. Plant one germinant per cavity. This will insure a virtually 100% stand. Return the ones that did not germinate to the cooler, and save them for the second crop.

Seed collection time would normally be September, and with 60 days' stratification, sowing could be scheduled any time after December 1. Let us schedule sowing for March 15. After 135 days in stratification, the acorns will germinate very quickly, so, no more should be brought out of the cooler than can be planted in 2 days. After the first crop is planted, the remainder of the acorns should be stored as cold as possible without freezing them to prevent germination in storage.

The first crop is expected to reach full height by the middle of June, at which time it can be transferred to a shadehouse to complete its caliper and dry weight growth, and the second crop can be started in the greenhouse. The second crop might reach full height in time to be hardened in the shadehouse, but that is not certain. Hardening in the shadehouse is cheaper than hardening in a greenhouse. The greenhouse can either be shut down for the winter, or another crop can be grown, preferably one that does not demand a lot of sunlight and has a relatively low temperature optimum. It would be possible to begin germination of crop 1 several weeks earlier, but this is pushing greenhouse operation into the expensive part of the year. Perhaps crop 1 could be removed from the greenhouse before height growth is completed, because it would have most of the summer to finish its growth. This is risky, because the oak will stop height growth unless the weather is hot and humid. Even in midsummer, that is often not the case in North Dakota. Therefore, assume the second crop will be hardened and overwintered in the greenhouse.

Germination.—Initial germination will occur in bags or trays at room temperature. After planting, the greenhouse should be set for about 70° F (21° C) day and night with the cooling set to hold temperatures under 81° F (27° C) until the seedlings are well established and the first set of leaves have expanded.

Relative humidity can be set at 70% with an allowable range of 50-90%. It is not necessary to give frequent light waterings to oak, because it is a large seed, and the bulk of it is 10-15 mm below the surface. Leaves should not have standing droplets of water on them for more than a few hours a day, because that invites fungal infection.

Photosynthesis of oak saturates at quite low sunlight intensities, and yet, bur oak can tolerate high light intensity. Shading is not necessary unless day temperatures cannot be held in optimum range. That range is high, however, and as often as not, intense sunlight may be beneficial to help raise the temperature.

We do not know for sure whether supplemental light is necessary to maintain height growth, but we do know it is ineffective unless temperature is kept high. Since intermittent incandescent light is not expensive, it would be advisable to have it on after the first leaves have expanded, just for insurance.

Watering should be as needed to keep the rootbal moist. The surface should dry between waterings, and no fertilizer is applied until the seed is largely used up, or until the majority of seedlings have their first leaves expanded. There is no point in turning on the high CO_2 until the first leaves are expanded either

Juvenile and multiple flushing stages.—There is little or no distinction between a juvenile and a more mature stage. Bur oak does not grow in height in a recognizable exponential fashion, but rather in very distinct flushes with pauses in between. Each flush, up to four, is roughly the same size.

After the seedlings are well established, the day temperature should be raised to about 90° F (32° C). An efficient way to do this would be to leave the furnace setting at about 75° F (24° C) and set the first cooling stage at 90° F (32° C) with full cooling on by 98° F (37° C). This may seem incredibly hot to some nurserymen, but it is the environment required to maintain multiple flushing of bur oak.

Relative humidity should be kept fairly high, because at high temperatures the transpiration stress is greater for a given relative humidity than at lower temperatures (table 11-1). Note that the combination of high temperature and humidity will make working in the greenhouse very uncomfortable, and jobs in the greenhouse should be scheduled for the early morning. Workers not used to the heat and humidity should eat enough salt, drink enough water, and take occasional breaks (Johansson and Mattsson 1975).

After the supplemental light and CO_2 are turned on and fertilization with each watering has begun, no further changes are needed until the crop has reached full height and is moved to the shadehouse. There are some cultural differences between oak and spruce (section 15.51) that should be noted, however.

The broad horizontal leaves of oak and other hardwoods shed water, which makes uniform watering harder and increases the edge effect. Because hardwoods generally grow faster and often transpire more, the available moisture in the pot mix does not last as long, and they must be watered more often as they grow. With hardwoods, it is easier to tell when they are moisture stressed, because wilting of the leaves is more obvious than with conifers. However, foliage is damaged more quickly, and it is important to avoid wilting during rapid height growth.

Hardwoods will grow at the same low pH used for conifers, but they seem to be healthier and grow faster when the nutrient solution is kept at pH 6-7. After watering with nutrient solution, the foliage is usually rinsed to remove salts and avoid leaf injury when the droplets dry. Conifer needles wash clean easily, but broadleafed hardwoods require more thorough rinsing.

Hardwoods require more protection against insects. Whereas conifers rarely have major problems, anything that can bite or suck will attack hardwoods. Every hardwood nurseryman should familiarize himself with the appearance of aphids, whiteflies, spidermites, and plant bugs, and the damage they cause. The best control is to clean out the house completely between crops, and then fumigate. Second, be vigilant. Insect populations start small and grow rapidly. Spot spray when harmful insects are first noticed. If populations are building, begin regular weekly spraying and rotate insecticides to catch a wider spectrum of insects and retard the development of resistance (section 20).

Hardening.—When the first crop is moved to the shadehouse, the nurseryman immediately loses control of temperature and humidity, and there will be no supplemental CO_2 or light at night. In mid-June, there should be no problem moving very succulent material out of the greenhouse, but the transition to cooler nights, probably cooler days, and much lower humidity, should trigger budset without any need to drought stress. Once in the shadehouse, watering should be as needed but with the low N, high PK formulation. This should be continued throughout the summer and fall as long as the day temperatures are above freezing and the rootballs are not frozen. About the time the rootballs begin freezing and after the leaves have fallen, bait the containers with rat poison and mulch around the sides and over the tops of the seedlings with sawdust, straw, coarse peat, or other suitable material. The shadehouse must be rabbit-proof. No other care is required until the stock is ready to be shipped in the spring. At this time, the mulch is removed, and the stock is watered thoroughly with high N nutrient solution just prior to shipment.

The second crop is handled exactly the same way through the germination and multiple flushing stages. On October 1, when hardening in the greenhouse begins, temperatures are reduced to levels that will stop flushing, set buds, and continue caliper growth, particularly in the taproot. It is not necessary to drought stress the seedlings to cause this.

Supplemental light at night is shut off to put the crop on a short photoperiod. This is standard procedure with all species, but unlike with conifers, the high CO_2 is also turned off. High CO_2 during the first stage of hardening is beneficial to evergreens, because it promotes caliper and dry weight growth. However, the high CO_2 must be turned off at the beginning of hardening of deciduous species, because CO_2 also retards leaf abscission and may promote bud break and renewed height growth.

Watering is continued as needed but with the low N, high PK formulation.

Another major difference between most conifers and most hardwoods is that the latter are deciduous, and normal abscission of the leaves is an important part of the hardening process. Accelerating leaf abscission has not been very successful. A number of investigators have sought chemical means to defoliate seedlings without damaging them. So far, nothing suitable can be recommended. Chemicals that effectively remove the leaves cause dieback the following spring.

Cold nights will cause the development of fall colors and begin the development of an abscission layer, but the leaves will generally not fall off until well into the second stage of hardening, in which the temperature is brought very close to freezing. No other changes in conditions are needed to go from the first to the second stage of hardening. These conditions are maintained throughout the winter. After 2 weeks at low temperatures, frosts will not hurt the seedlings, but the rootballs should not be allowed to remain frozen for weeks at a time.

The second crop will have to be removed from the greenhouse before about March 7 so that the next year's first crop can be planted. This can be done anytime after December 15. They should be moved to the shadehouse in mild weather, if possible, and the seedlings should be placed flat on the ground and mulched immediately just like the first crop. Both crops will be ready to ship for spring planting.

15.53 Large Ponderosa Pine for the Southwest

In this example, we need a husky seedling with a 6-inch (15-cm) top and ¼-inch (6-mm) caliper ready for outplanting about July 15 (Appendix 2). In the Southwest, mid- to late summer is the best time to plant, because that is when the rains come. A cold hardened seedling is not necessary, but the top should not be actively flushing. This means it should receive the first stage of hardening, but not the second. Hardening must begin about June 7 if we allow 5 weeks. To be sure that a large enough seedling can be grown, allow about 22 weeks from seed, which means seeding the first week in January. In New Mexico or Arizona, winter does not pose the same problems for greenhouse operation that it does in colder, high latitude climates. Day length, sun angle, and sunlight intensity are generally still favorable even in December and January. Heat requirements to maintain growing temperatures are within reason in a properly designed facility.

Germination.—Conditions for ponderosa pine germination are not very different from white spruce in the first example (section 15.51). The seed usually does not need stratification, and 70° F (21° C) day and night is a good germination temperature. Relative humidity should be kept high and the surface always moist until germination is complete. Use no fertilizer until the seed coats are shed.

Shading may or may not be necessary. Sunlight intensity in January is near its minimum, but some nurseries may be located at fairly high elevation (4,800-8,000 feet or 1,200-2,500 m). If it is hard to keep the soil surface moist and the temperature down to 70° F (21° C), then shade; otherwise don't.

Juvenile stage.—In ponderosa pine, the juvenile stage is distinct and may be defined as the period between the shedding of the seedcoat and the appearance of buds and needle fascicles. As soon as the seedcoat is shed, begin fertilization with high N nutrient solution of about pH 5.5. Turn on the high CO_2 whenever the vents are closed during daylight hours. Turn on the supplemental light at night to lengthen the photoperiod. This is not as critical with a low latitude seed source as it was in white spruce (section 15.51), but it is cheap insurance against premature budset, which could delay reaching full size, and there is an appreciable growth response both in height and dry weight.

As the seedlings grow older, they can use more light and higher temperatures. Excessive temperatures must be avoided, especially before the hypocotyl lignifies and develops some bark.

Multiple flushing and exponential growth.—The seedling will grow exponentially until the first buds appear. Thereafter, there will be periods of elongation interspersed with budset. Each successive flush tends to be larger than the previous one until the crowns close and the container size becomes limiting. As long as nearly optimum conditions are maintained, budset should cause no alarm.

Sunlight intensity will gradually increase with the advancing season, and so will the capacity of the seedling to use it. For most, if not all, of the growth period, shading should be applied only if near optimum temperatures cannot be maintained.

Hardening.—Only the first stage of hardening is needed, but time is likely to be short. To maximize the rate of hardening, the first step is to water heavily to leach out N. Then allow to dry to the wilting point. This will occur the second week in June, when greenhouse temperatures could become hot and humidity is quite low. The drying will have to be monitored closely. If there is much non-uniformity of conditions, some trees will be much drier than others and may have to be spot watered by hand, so that the remainder can continue to dry. When the trees have reached the wilting point, they are rewatered with low N, high PK solution, and thereafter watered with the same as needed.

Hardening may be done either in the greenhouse or a shadehouse. In either case, supplemental light a night and the high CO_2 are turned off. In the greenhouse, it will probably be difficult to keep day temperatures down below 75° F (24° C). Shading wil certainly be necessary, but evaporative cooling in the dry climate of the Southwest is very efficient and effective. Moving the seedlings to a shadehouse wil subject them to much lower humidities than in the greenhouse. They will need good wind protection and shading down to perhaps 30% of full sunlight. The containers should remain up on racks to permit air pruning.

By July 15, the buds should be well set and the stem fully lignified. They should be well watered and fertilized with high N nutrient solution immediately prior to shipment. After outplanting, root growth should be extensive, but renewed top growth that season is unlikely.

15.54 Other Examples of Growing Schedules

Appendix 2 contains a collection of growing schedules developed for individual nurseries. They are presented as models to further illustrate the strategy for growing the desired product. In certain cases, they may fit a new operation closely enough to be used as a first try with little modification, but, in most cases, they will require some changes to fit local conditions.

SECTION 16.—SEED AND SOWING

16.1 Propagation Materials and Methods

16.11 Seed Quality

16.12 Seed Source Identification and Its Importance

16.2 Filling the Containers

16.21 The Growing Medium—Operational Considerations

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SECTION 16.—SEED AND SOWING

16.1 Propagation Materials and Methods

Most trees grown in forest tree seedling containers are conifers. Most of this production is in the western United States, with a limited amount in the South and East (McDonald 1977). A few broadleaf tree seedlings are reared in containers in the Plains states for shelterbelts and windbreaks. Nearly all of these trees, both conifer and broadleaf, are propagated from seeds. Very few container trees are propagated from cuttings, with the exception of some cottonwood in the Plains and South. However, considerable research is underway on vegetative propagation of conifers, mainly oriented toward acquiring genetic gains more rapidly. The reader should expect vegetative propagation to be increasingly used in nursery operations in the future.

Considerable work is being done on greenhouse propagation of native shrub and grass species. Forest seedling tree containers are sometimes used. Such shrub seedlings and grass plugs are valuable in disturbed land revegetation projects, range improvement, and park landscaping (Cable 1974). Seed for these plants is usually scarce, and greenhouse propagation yields the most plants for the available seed.

16.11 Seed Quality

Generally, only very high quality seed should be used, because it is costly to carry blank cavities through the growing cycle in the greenhouse and to thin excess seedlings from the containers. High quality seed helps avoid both situations by providing reliable germination with the use of fewer seeds per cavity. From the seedling production probability tables in appendix 3 (Balmer and Space 1976), it can readily be seen how high quality seed can provide seedlings in most cavities, requiring little thinning.

As a rule of thumb, seed with viability lower than 50% should never be used in CTS operations, and 75% is minimum under most circumstances. Many CTS operations "size" their seed prior to stratification. "Sizing" means taking only the largest and heaviest one- to two-thirds of a seed lot. Sizing may result in more reliable establishment and higher total germination percentage, because those seeds that are full and that have the largest endosperm capacity are selected. Some geneticists are concerned that seed sizing reduces the genetic base, because seed size tends to be a characteristic of the parent tree. However, seed size also varies from one crop to the next on the same tree. Consequently, when this is the case and seed crops are available over a period of years, seed sizing would not discriminate against individual parent trees nearly as much as it might in any one year. Tinus (1978) has shown this to be true of Scotch pine.

However, many western conifers do not have seed crops every year. Nurseries rely heavily on infrequent heavy seed crops for their production. This maximizes the discrimination against certain parent trees. It is not hard to show that seed sizing has operational advantages at the container nursery, but it may be quite difficult to demonstrate that seed size is genetically linked to other traits we want to preserve in the next generation.

In cases where seed is very valuable, as from tree improvement experiments, every seed may be sown, even though the average viability may be low. In such instances, relatively few seeds may be sown per cavity and numerous blanks accepted, or excess trees in some cavities may be transplanted to empty cavities by hand. Expensive or rare seeds or seeds that do not germinate evenly may also be germinated in flats and then placed in the container. This procedure is used with some species of native shrubs and with walnut, oak, and pecan (Tinus 1977). This procedure also allows blocks of containers to be grown with seed that all germinated about the same time. Several blocks of trees or shrubs of different size levels are thus created as the seeds germinate, but plants within a block are more or less uniform. Such procedures are expensive, but the alternative of oversowing, a great deal of thinning, seed wastage, and inter-plant competition and suppression is expensive, too.

Knowledge of the quality of seed used at a tree nursery is essential. Sowing tree seed without adequate seed test data and carefully calculated sowing rates is archaic and wasteful. This is especially true in CTS production. Excellent tree seed testing services are available from a number of seed laboratories in the United States.

16.12 Seed Source Identification and Its Importance

Source identified seed should be used in all CTS operations. This identification should be preserved through the growing process, and trees produced should be planted at or near to the original seed collection site (in accordance with locally accepted rules established by professional forest geneticists). Production of source identified seedlings will identify the nursery as a truly professional operation. The dangers of planting stock that is not well adapted to the site are well known. Failure of containerized trees due to genetic incompatibility with the planting site can question the creditability of nursery, the container system, and the parent forestry organization. Finally, nurserymen are entrusted to produce trees that will live and grow. By distributing stock of unknown origin for widespread planting, the nurseryman betrays trust placed in him.

16.2 Filling the Containers

To unitize and fill the containers requires the growing medium, the containers, a place to work, the labor force to do the job, and a system or plan to do the work.

16.21 The Growing Medium—Operational Considerations

The component parts of the growing medium must be on hand in sufficient quantities to provide adequate medium for the whole job. The combination of components and a small amount of water should take place in bulk a few days before the filling operation (see section 9.34). At container loading time, be sure the mixture is uniformly mixed, with the proper moisture content. Ideally, the peat and vermiculite should be kept sealed in plastic or paper bags up to mixing time. The mixing equipment and area should be cleaned before, and every couple of days during the process. The medium should be covered with clean plastic film to prevent drying and contamination when not in use.

16.22 The Containers

If the containers have been used for a previous crop, they should have been sanitized before re-use. For efficiency, damaged containers should be sorted out and discarded prior to the filling process. Those requiring assembly or placement into racks or trays can be set up in advance.

16.23 Work Location

The area for the mixing operation should be (1) large enough to do the work (i.e., encompass the workers, equipment, and materials), and (2) be free of contaminants such as soil, dust, etc. A building with a smooth concrete floor is best. Having this work area near the greenhouse(s) is a distinct advantage.

16.24 Labor Force

Enough labor should be employed to assure smooth functioning of the filling operation. This operation is usually short term for a variety of reasons, so, large amounts of labor can be employed economically. Adequate supervision will assure a high quality, fast moving operation.

16.25 A Work System or Plan

A plan is needed to allow completion by a certain date. This plan should provide for smooth, fast progress of the container filling through the sowing process. Unanticipated problems are sure to arise, but good preplanning should minimize them by helping isolate equipment shortages and bottlenecks in advance. A simple schematic diagram of the materials flow and work stations is usually helpful.

The container filling process integrates growing medium, containers, work area, equipment, and labor into a high intensity production effort that takes place over a relatively short period of time. This work can consume a large part of a CTS nursery budget, so, every effort should be made to do the work efficiently and rapidly. The degree of mechnization of the process depends on the size and sophistication of the operation. Containers can be filled with growing medium and stored. The work area can then be converted to a seeding and seed covering operation. This process can make the best use of a limited work area or a few workers, and the whole crop is started nearer to the same time. However, the filled containers have to be handled an extra time, and the growing medium must be kept moist.

16.3 Sowing Seed in the Containers

Equipment used for sowing and covering the seeds is discussed in section 7.3. The equipment and methods used vary widely.

16.31 General Sowing Considerations

The number of seeds that will germinate and result in an established seedling is correlated directly with seed viability. In CTS nurseries, the difference between the germination test percentage and the actual number of trees produced is less than in a conventional nursery. This is because environmental factors are controlled, optimized, and the growing medium is sterile. The size of these differences in CTS nurseries is not well known. Good records can pinpoint what such sowing factors actually are, but knowing them is not nearly as critical in CTS nurseries as in bare-root nurseries. This is because CTS nurserymen habitually oversow to acquire the maximum number of filled containers, not total trees germinated. Only a few blank containers can be tolerated, because greenhouse growing space is costly. The number of seeds to sow in each container must be decided. Probabilities of achieving tree establishment for a certain number of seeds sown per container is the crux of the sowing process.

Quality of seed is important. Probability tables provide estimated numbers of seedlings to be produced from seed. Earlier, it was recommended that seed with viabilities below 75% should not normally be used. This is because sowing large numbers of seed per cavity requires (1) many repetitions of the sowing process per container, and (2) excessive thinning later on. Also, as the quality of seed declines, there is generally an increasing divergence between the number of live seeds according to a germination test and the number that will develop into self-sufficient tree seedlings. If very low quality seed must be used, consider sowing germinated seed. The same applies to rare, costly, or uneven germinating seed. In some cases, the sheer size of the seed precludes putting more than one in a container. With very large seeds, the orientation of the seed and radicle is important. Walnuts should be centered in the container with the nut on its side, with the seam between the halves vertical, and the radicle end of the nut pointing toward a corner of the container; pecans and acorns should be placed in a corner or against one wall with the radicle end pointed toward the center of the container (or radicle pointed down if developed to any degree) (Tinus 1977a). With such large seeds a large container is needed. The point is that, for some species and instances, manual planting of germinated seeds is best.

The type of container used, the greenhouse space available, the local labor costs, the external pressure to reliably produce trees, the current price for containerized seedlings, fuel costs, and seed availability all can influence the nurseryman's decision on how many seeds to place in each cavity.

Container used.—In book or block style containers (section 9.2), if a tree does not develop in a cavity, it must be left in the unit. A seedling must be transplanted into it for it to be a productive cavity. The tendency should be to oversow at the outset to ensure a high percentage of filled cavities.

Empty cells of cell container systems can be removed from the unit racks on an individual cell basis. Consequently, the grower can sow extra cells and replace blank cells with the extra full ones. The strategy here might be to sow fewer seeds per cavity to reduce thinning, and to sow extra cells to replace blank ones.

Greenhouse space available.—If greenhouse space is limited and demand for seedlings is high, there may be justification for placing more seeds per container. This is the case if high priority on maximum production overrides possible added thinning costs.

Local labor costs.—High local labor costs can discourage oversowing in an effort to avoid high thinning costs. It may be cheaper to carry added blank cavities and do less thinning and transplanting. However, relatively low local labor costs may encourage the converse.

Fuel costs.—Fuel costs would affect seed sowing about the same way labor costs do, but in just the opposite way. High fuel costs encourage maximum greenhouse productivity, and, therefore, encourage oversowing per cavity.

Profit margin.—A high profit ratio on containerized tree seedlings encourages oversowing to maximize production, even if this elevates unit production costs. Smaller profit margins compel the nurseryman to minimize unit production costs to maximize unit production profits, not mass production profits, as in the first case. Space and Balmer (1977) have developed a computer program that provides the optimum number of seeds to sow per cavity to minimize seeding, transplanting, and thinning costs for a given seed quality and cost factors for the seed, sowing, thinning, and transplanting at a nursery. Figure 16-1 is a sample of a printout from this computer program. To use this potentially valuable tool, the CTS nurseryman must estimate, or have records of, the unit costs for the labor associated with the various activities in his operation. The program entitled, "Minimum Cost Calculations for Container Planting" published in January 1977, is available from the USDA Forest Service, Atlanta.

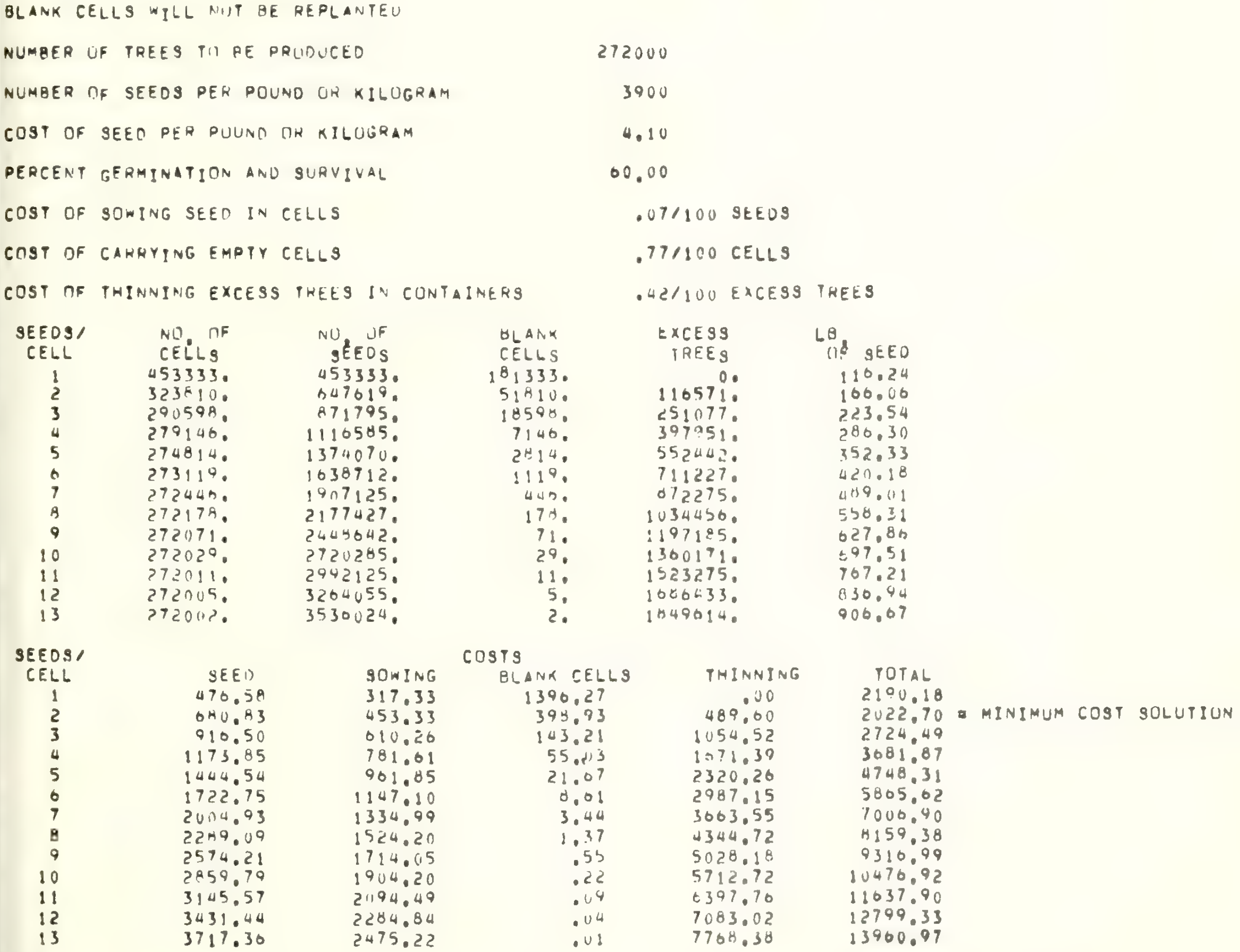
Seed availability.—Seed shortages tend to prevent oversowing in each cavity and encourage transplanting excess trees from one container to blank ones. Adequate supplies of seed help assure the most economical operation of CTS nurseries.

16.32 Procedure

The sowing procedure actually begins with determination of how many trees of what species and seed source will be grown. The steps leading up to sowing are:

a. Determination of seed needs
b. Stratification of the seed
c. Preparation of stratified seed for sowing
d. Sowing

Determination of seed needs.—The task of the nurseryman is to translate production goals into tree seedlings. The following example is reproduced from Space and Balmer (1977):



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BLANK CELLS WILL NOT BE REPLANTEU

NUMBER OF TREES TO PE PRODUCED                      272000

NUMBER OF SEEDS PER POUND OR KILOGRAM                 3900

COST OF SEED PER POUND OR KILOGRAM                    4.10

PERCENT GERMINATION AND SURVIVAL                     60.00

COST OF SOWING SEED IN CELLS                           .07/100 SEEDS

COST OF CARRYING EMPTY CELLS                           .77/100 CELLS

COST OF THINNING EXCESS TREES IN CONTAINERS            .42/100 EXCESS TREES

 SEEDS/        NO. OF         NO. OF          BLANK          EXCESS        LB
  CELL         CELLS          SEEDS           CELLS          TREES        OF SEED
    1        453333.        453333.         181333.              0.        116.24
    2        323810.        647619.          51810.         116571.        166.06
    3        290598.        871795.          18598.         251077.        223.54
    4        279146.       1116585.           7146.         397951.        286.30
    5        274814.       1374070.           2814.         552442.        352.33
    6        273119.       1638712.           1119.         711227.        420.18
    7        272446.       1907125.            446.         872275.        489.01
    8        272178.       2177427.            178.        1034456.        558.31
    9        272071.       2449642.             71.        1197185.        627.86
   10        272029.       2720285.             29.        1360171.        697.51
   11        272011.       2992125.             11.        1523275.        767.21
   12        272005.       3264055.              5.        1686433.        836.94
   13        272002.       3536024.              2.        1849614.        906.67

 SEEDS/                                  COSTS
  CELL          SEED          SOWING      BLANK CELLS       THINNING       TOTAL
    1         476.58          317.33        1396.27             .00       2190.18
    2         680.83          453.33         398.93          489.60       2022.70 = MINIMUM COST SOLUTION
    3         916.50          610.26         143.21         1054.52       2724.49
    4        1173.85          781.61          55.03         1671.39       3681.87
    5        1444.54          961.85          21.67         2320.26       4748.31
    6        1722.75         1147.10           8.61         2987.15       5865.62
    7        2004.93         1334.99           3.44         3663.55       7006.90
    8        2289.09         1524.20           1.37         4344.72       8159.38
    9        2574.21         1714.05            .55         5028.18       9316.99
   10        2859.79         1904.20            .22         5712.72      10476.92
   11        3145.57         2094.49            .09         6397.76      11637.90
   12        3431.44         2284.84            .04         7083.02      12799.33
   13        3717.36         2475.22            .01         7768.38      13960.97
```

Figure 16-1.—Sample printout showing least cost solution to a sowing problem (Space and Balmer 1977).

Laboratory seed tests provide germination percent, purity, expected survival, and seed per pound for each seed lot. A nurseryman can calculate the number of seeds needed per cell to provide a given number of filled cells by the use of probability formulas. In addition, by determining the numbers of blank and filled cells, the number of excess seedlings that will have to be replanted or removed by thinning can also be predicted. Balmer and Space's (1976) tables can save the nurseryman the trouble of making many sowing calculations by hand (probability tables are provided in appendix 3). From that publication the authors have drawn the following examples to illustrate this:

"Assume 250,000 seedlings are desired, and test of seed lots indicate a 75% germination rate and expected survival rate of 60% and 20,100 seeds per pound (44,300 per kg): tables 16-1 and 16-2 show the calculations for two options using 60% expected survival and comparing the use of two and three seeds in each cell.

"If two seeds are sown per cell, option 1 indicated 120,000 cells would not need thinning or replanting. Containers seeded to three seeds per cell would have 72,000 cells not requiring thinning or replanting. Cost of seed, containers, and thinning, would be lowest for two seeds per cell, and cost of replanting would be lowest for three seeds per cell, with 16,000 blank cells. Under Option 2, cost of containers and media would be lowest, when three seeds per cell are used. Cost of seed and thinning would be lowest for two seeds per cell.

"The same comparison between the two approaches can be made for larger numbers of seeds per cell. While computations are more involved, the tables can be used to predict the number of seedlings per cell when seeding methods used produce a range in the number of seeds per cell. Sampling seed containers will provide the information necessary to carry out the computation. Table 16-3 is an example of this procedure using the 60% expected survival rate and 250,000 cells: from a sample count after sowing, 5% of the cells were blank, 20% contained one seed, 36% contained two seeds, and 39% contained three seeds.

"From this information, the nurseryman can estimate the number of seedlings that will require thinning, and the number of cells that will be blank. If replanting blank cells is planned, he can determine if the extra seedlings will be sufficient for replanting needs or how many seedlings he needs to raise in flats.

"The importance of using high quality seed can be readily seen by examining the probability tables. For two seeds per container the number of blank cells changes from 4 per 100 cells at 80% germination to 16 per hundred at 60% germination.

"A nurseryman can use the information developed from the probability tables to select the cost effective seeding rate, utilize seed to the best advantage and estimate future costs related to seeding practices. For example, if containers with 272,000 cells are to be used and excess seedlings are to be replanted as needed with the balance to be removed by thinning, estimated costs and seed requirements can be calculated. Suppose the seed used has a 60% germination rate, costs $4.10 per pound, and has 3,900 seeds per pound. Estimated costs in this case are: 7¢/100 for sowing seed; 98¢/100 containers replanted; and 42¢/100 for excess trees removed by thinning. Under these estimates the following figures would apply:

	Seeds per cell	
	2	3
Pounds of seed	140 (63.5 kg)	210 (95.3 kg)
Seed costs ($)	574	861
No. seeds	544,000	816,000
Sowing costs ($)	380	571

"The estimated number of containers to replant for two seeds per container will be 0.16 x 272,000 + 43,250 and for three seeds per container will be 17,408. Excess seedlings resulting will be 54,400 in the cells with two seeds and 217,600 in the cells with three seeds.

"Costs for replanting and thinning would be:

Seeds/Cell	Replanting	Thinning
2	$426	$228
3	$171	$913

Total costs for seed, sowing, replanting, and thinning would be $1,608 when two seeds per cell are used and $2,516 when three seeds per cell are used."

There are simpler less exacting, ways to figure seed needs using rules of thumb such as: for germinations from 60-75% use three seeds per cavity; 75-85% use two seeds; 85-99% use one seed, etc.

These sowing rules are generally arrived at by trial and error and refined through experience. They can work very well or very poorly. The authors recommend the method outlined by Space and Balmer (1977), because it uses the best information in an effective way.

Seed stratification.—Many tree seeds germinate more uniformly if they have been stratified. If this is not done, many tree seeds will germinate intermittently over a long period. Intermittent and prolonged germination is intolerable in a greenhouse. Seeds of some conifer species may germinate reliably in 2 weeks without stratification. Where this is known, stratification is not warranted. Where germination takes longer, seed should be stratified.

Table 16-1.—Option 1. Calculation of seed required and seedlings produced assuming a 60% survival rate, replanting blanks with extra seedlings, and thinning the remainder.

Total no. of cells needed	No. of cells by predicted[1] no. of seedlings per cell				Total no. of seedlings predicted	Pounds of seed required
	Blank	1	2	3		
Using 2 seeds per cell						
(1.00)	(0.16)	(0.48)	(0.36)			
250,000	40,000	120,000	90,000		[2]300,000	[3]24.9 (11.3 kg)
Using 3 seeds per cell						
(1.00)	(0.064)	(0.288)	(0.432)	(0.21)		
250,000	16,000	72,000	108,000	54,000	450,000	37.3 (16.9 kg)

[1] *Figures in parentheses are percentages taken from appropriate probability table.*
[2] *Expect 120,000 cells with one seedling + 2 x 90,000 cells with two seedlings = 300,000.*
[3] *Number seeds sown divided by seeds per pound (i.e., 250,000 x 2 ÷ 20,100 = 24.9).*

Table 16-2.—Option 2. Calculation of seed required and seedlings produced assuming a 60% survival rate and thinning only.

Total no. of cells needed	No. of cells by predicted[1] no. of seedlings per cell				Total no. of seedlings predicted	Pounds of seed required
	Blank	1	2	3		
Using 2 seeds per cell						
[4](1.00)	(0.16)	(0.48)	(0.36)			
297,619	47,619	142,857	107,142		[2]357,141	[3]29.6 (13.4 kg)
Using 3 seeds per cell						
(1.00)	(0.064)	(0.288)	(0.432)	(0.216)		
267,094	17,094	76,923	115,384	57,692	480,767	39.9 (18.1 kg)

[1] *Figures in parentheses are percentages taken from appropriate probability table.*
[2] *Expect 142,857 cells with one seedling + 2 × 107,142 cells with two seedlings = 357,141.*
[3] *Number seeds sown divided by seeds per pound (i.e., 297,619 x 2 ÷ 20,100 = 29.6).*
[4] *Divide number of seedlings desired by total percent of cells predicted to have seedlings, i.e., 250,000 ÷ (0.48 + 0.36) = 297,619.*

Table 16-3.—Prediction of number of seedlings per cell by seed count.

Seed cell	Number of cells	No. of cells by predicted[1] no. of seedlings per cell				Total no. of seedlings predicted
		Blank	1	2	3	
Blank	12,500	12,500				
		(0.40)	(0.60)			
1	50,000	20,000	30,000			30,000
		(0.16)	(0.48)	(0.36)		
2	90,000	14,400	43,200	32,400		108,000
		(0.064)	(0.288)	(0.432)	(21.6)	
3	97,500	6,240	28,080	42,120	21,060	175,800
Total	250,000	53,140	101,280	74,250	21,060	313,500

[1] *Figures in parentheses are percentages taken from appropriate probability table.*
[2] *Estimate 43,200 cells with one seedling + 2 × 32,400 cells with two seedlings = 108,000.*

Stratification of conifer seeds usually means exposure of the seed to low temperatures (32-50° F; 0-10° C), and moist conditions for 1-6 months (Schopmeyer 1974). Often, the seeds are subjected to a moist, warm soak before chilling. The mechanics of the stratification procedure vary and can be accomplished in a number of ways. Probably the best and most comprehensive reference on the subject is Schopmeyer (1974). This publication provides species by species guides for stratification.

Preparation of stratified seed for sowing.— Conifers usually require a cold moist stratification. This means the seed will have to be surface dried at low temperature to be dry enough to flow through seed handling machines. Seed coats of some tree seeds may harbor spores of pathogenic fungi. In such cases, surface sterilization with 30% hydrogen peroxide or 1% sodium hypochlorite may be useful. The time of soaking will vary with the species, but all seed should be thoroughly washed with running water following treatment (Barnett 1976, Riffle and Springfield 1968). However, this treatment should only be used where necessary and when it has been tested on the species in question. Improper application can damage the seed.

Surface dried seed is sometimes mixed with talc to promote smooth flow through seed sowing devices and to minimize seed stickiness.

Sowing seed into the containers.—Sowing equipment and methods are described in section 7.3. The prime conditions of the sowing operation are accuracy and efficiency. Accuracy means putting the exact number of seeds desired into as high a percentage of the cavities as possible. Also, it is best if the seed is placed in the center of the cavity when sowing conifer seed. A dish shaped depression in the surface of the growing medium can be created as described in section 7.2. The seed is normally not firmed into the medium, but rests on its surface in the depression.

16.33 Covering the Seeds

In CTS nurseries, the seeds are normally covered with a thin layer of crushed rock (poultry grit) or perlite. In a few instances, the seed is covered with a thin layer of growing medium, ground bark, sand, or not covered at all. Conifer seed should generally be covered with grit or perlite. Covering with organic materials or materials such as fine sand promotes proliferation of mosses, fungi, liverworts, etc., on the surface of the cavity. This tends to inhibit water infiltration into the potting medium. Perlite and grit particles should be no less than 2-3 mm in diameter. With some brands of perlite, smaller particles may have to be screened out. In the proper size range, both perlite and grit provide several positive effects.

1. They shield the seed from the direct rays of the sun, but allow diffuse light to reach it. This aids germination in some species (Harrington 1977).
2. They provide some minimal weight on the seed which facilitates mechanical entry of the radicle into the growing medium.
3. They are sterile and provide a droughty surface, uninhabitable by moss, liverworts, and fungi.
4. They are readily permeable to water.
5. They are particulate and more or less uniform, which facilitates mechanical application of thin layers of them to the surface of the containers.

Perlite has the added advantage of being lightweight, but can be blown away, floated away, or knocked out of the cavity by impacts of large water drops. Grit will stay in place, but adds appreciable weight. The layer of perlite or grit applied should vary from zero or very thin layers for small seeds up to about 5 mm for large seeded species. Some small seeded conifers, such as Engelmann spruce, may do well with no covering.

Fast growing or large seeded broadleaf species can be covered with growing medium, because they emerge and shade the containers in a short time. This shade inhibits moss and liverwort development, so, water infiltration into the growing medium never becomes a problem.

The depth of seed covering applied to any species should be as uniform as possible to facilitate uniform plant growth and development.

SECTION 17.—GROWING THE TREES

17.1 Germination, Thinning, and Transplanting

17.11 Germination Conditions
17.12 Covering Containers During Germination
17.13 Completion of Germination
17.14 Thinning
17.15 Thinning Procedures
17.16 Other Thinning Considerations
17.17 Transplanting

17.2 Juvenile Development and Exponential Growth

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17.3 Caliper Development and Cold Hardening

17.31 Caliper Development and Cessation of Apical Growth
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17.4 Movement of Trees to a Shadehouse

17.41 Strategy for Use of Shadehouses
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SECTION 17.—GROWING THE TREES

When the containers have been filled, seeded, and moved to the greenhouse, the actual growing of the trees begins. These procedures fall into three phases: (1) germination, (2) juvenile development and exponential growth, and (3) caliper development and cold hardening. Each phase is characterized by differences in the seedlings and the greenhouse environment.

17.1 Germination, Thinning, and Transplanting

Germination, thinning, and transplanting all occur in a relatively limited period of time after the seeded containers are placed in the greenhouse. As mentioned in section 16, the greenhouse should be loaded with all the seeded containers at about the same time so that the trees get off to an even start. This promotes crop uniformity and helps the operator of the greenhouse determine when germination is complete. The greenhouse environment can then be altered to promote growth instead of germination. The greenhouse should be loaded in no more than 2 to 3 days. This may mean some container units have to be filled, seeded, and stored while the rest are seeded. Seeded containers should be kept in high humidity cold storage conditions to retard drying and seed germination.

17.11 Germination Conditions

During the germination period, seeds are kept moist and reasonably warm (65°-70° F or 18°-21° C). Higher temperatures may result in germination of conifer seed, but may also result in excessive hypocotyl development. Frequent light watering may be needed. Overwatering should not cause the problems common when plants are grown in soilbased media. The humidity of the greenhouse atmosphere should be in the 60-80% range. In single layer greenhouses, in cold weather, even supplemental watering or other humidification may not be able to maintain these levels.

17.12 Covering Containers During Germination

In many horticultural operations and some CTS nurseries, the flats of seed to be germinated are covered with plastic to reduce evaporation and keep the seeds moist with a minimum of irrigation. Some precautions must be taken when using plastic coverings.

Black plastic, or other completely opaque, impermeable covering materials can become very hot from the sun. Also, light stimulates germination of many tree seeds. These light levels are not high (75-125 foot-candles), but are important to germination (Association of Official Seed Analysts 1970). Section 16.33 notes that one of the reasons for using coarse particles is to allow diffuse light to reach the seeds. For these reasons, black plastic is not recommended for covering containers during germination.

Clear plastic sheeting can be used to cover containers. However, the layer of clear plastic can trap enough solar energy to cause unacceptably high temperatures under the film. Its use is not recommended. The best covering lets some light through to the containers, but not too much. White polyethylene sheeting will do this. Clear plastic sheeting with a layer of butcher paper or newspapers over it will also work.

In CTS greenhouses with both germinating seeds and actively growing trees, covering containers containing germinating seeds will keep the seeds moist without frequent watering, which might not be good for the established seedlings. Covering the containers during germination is not required but simplifies maintaining optimum germinating conditions for the seeds, but the covering must not create complete darkness or high temperatures.

17.13 Completion of Germination

If properly stratified prior to placement in the greenhouse, germination of most conifer seeds should be complete in 10 to 25 days (average 15 days). It is judged to be complete when: (1) most of the seeds have germinated, (2) most conifer seed coats have been shed, (3) the root systems of the trees have grown into the growing medium. If the containers have been covered, the cover should be removed before the seedling shoots are pressing against it. As the seedling develops, water less often to let the soil surface dry between waterings. Greenhouse temperatures and humidity levels are changed to those best for the juvenile growth phase of the tree species in question (section 15.3). In greenhouses where northern latitude tree ecotypes are grown in fall and winter, lights should be turned on at night for dormancy control immediately after germination is complete.

17.14 Thinning

More than one seed is usually sown per container cavity to assure most cavities are finally occupied by at least one tree (section 16.32). This results in cavities being occupied by more than one tree.

Extra trees are removed once the seedlings are judged to be sufficiently established. Thinning is started when: (1) the seed coats have been cast off, (2) the crop has been on the juvenile environmental control regime for at least a week, and (3) the danger of serious losses to damping off fungi appears to be diminished.

17.15 Thinning Procedures

There are two thinning procedures that are normally used—whole tree removal and clippings. Whole tree removal is the recommended procedure. It involves removal of the seedling, root included, from the container. This can continue until seedlings develop lateral roots, usually 3-4 weeks after germination for western conifers. When lateral roots develop to the point where seedling removal is seriously disrupting the growing medium and the seedling left in the container, whole tree thinning should be stopped. Consequently, western conifers can be thinned during about 2-3 weeks. It is important the work does not start before germination is complete, because rethinning may be required to remove late germinants. To get the job done in the limited time available, the nursery crew has to be large enough. Estimated production rates can be based on thinning rates recorded in past years or by working a small thinning crew to start with, observing production per man day, then adjusting the crew size accordingly.

After lateral roots develop, any excess trees remaining will have to be clipped at ground level with scissors. This is less desirable than removing the entire tree, because it is easy to inadvertently cut off the residual crop seedling, too. Also, the roots of the excess trees are left in the container. This dead organic matter can become the substrate for pathological organism development.

Clipping is best done before appreciable inter-seedling competition develops. This avoids growth losses from competition. However, the timing is not as critical as with whole tree removal, and clipping can go on up until the time that the trees are shipped.

Whichever method is used, thinning must be done with sufficient care so that the remaining seedling is undamaged. There is disagreement as to whether whole tree removal or clipping is more likely to cause inadvertent removal of the remaining seedling.[1] Such mistakes can be minimized by holding the tree to remain with one hand and pulling or clipping the rest with the other.

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[1] *Personal communication with Phillip Hahn, Georgia-Pacific Corp., Eugene, Oreg., May 1978.*

17.16 Other Thinning Considerations

In either type of thinning operation, the trees or tree parts removed should be placed in refuse containers (cans, boxes, etc.) as the work proceeds. This refuse should be removed from the greenhouse each day. Leaving these dead plant parts scattered in the greenhouse is an invitation to disease and insect problems.

Bench design should take into account that workers must be able to reach each cavity (section 7.4). Thinning is tedious and rather exacting work, and if it must be done from a strained or unorthodox position, production inevitably suffers, and labor costs can soar.

17.17 Transplanting

Some CTS nurserymen transplant thinned seedlings into the blank cavities which contain no successful germinant. Since those seedlings removed in the whole tree thinning method have few or no lateral roots, transplanting them is easy but time consuming. Holes are made in the center of the growing medium in the blank containers with a sharpened pencil, nail of sufficient size, or a table knife. The seedling's root is placed in the hole and the medium is pressed against the roots to close the hole. This same procedure is followed when placing the plants germinated in flats into CTS containers. Transplanting is difficult and less successful when the containers are covered with perlite or grit.

The economics of transplanting are questionable. Some seedlings inevitably die from transplanting shock. Assessments of these losses and labor costs to do the work will determine if transplanting is economical. The cost of transplanting is usually quite high. For this reason, it should be avoided if possible. Data should be collected on just what the operation does cost and how many more plantable seedlings are produced so such judgments can be made from accurate figures.

17.2 Juvenile Development and Exponential Growth

17.21 Characteristics

During this period of CTS crop production, the nurseryman operates the greenhouse in accordance with the environmental conditions specified in the growing schedule and monitors greenhouse equipment function (section 15.34, 15.35). Records on activities and instrument readouts are kept. The crop is observed daily for disease or insect problems and for proper growth, color, etc. Excess trees are removed and empty containers are filled with transplants, as desired.

17.22 Greenhouse Operation

The environmental parameters controlled are those listed in section 15 dealing with guides for formulating growing schedules. The greenhouse needs to be programmed to provide the specified environmental conditions. In new greenhouses, this may require mechanical adjustments and modifications beyond routine adjustment of time clocks, set points, injector calibrations, etc. As seasons change, these adjustments and settings may have to be altered to cope with changes in the outside environment. A detailed record of these changes should be kept for future reference (section 18.2). Records of all cultural activities (section 18.3), instrument readings, and condition of seedlings should be kept also (section 18). Such records are valuable when planning another crop or when tracking down the reason for a problem with a crop. Trends in leachate pH and EC readings should be charted (section 18.34). The crop should be constantly monitored for insect, disease, or animal damage, and abnormal plant development in general. Corrective action must be taken when evidence of damage or abnormalities are observed (section 21).

17.23 Difference between Juvenile and Exponential Growth Stages

The most visible difference between juvenile and exponential growth periods is the nature of the foliage. The first leaves are often morphologically different than mature foliage and may form a rosette above the cotyledons. Length of this period will vary with the species. Culturally, the main difference is that during the juvenile stage, lower light intensity is recommended to reduce moisture stress and avoid solarization. Thinning usually is done early in this period. Also see sections 15.23, 15.34, and 15.35.

The exponential growth period is characterized by rapid shoot elongation, development of mature leaf forms, and proliferation of roots. Growth will be exponential during this period unless one or more factors become limiting. This does not mean that height growth is continuous; buds may set between flushes of growth. Every effort must be made to keep the environment for the seedlings as close to optimum as possible during this period. Malfunctions in equipment or inattention to seedling needs, such as irrigation, can result in apical dormancy that will extend the time to crop maturity for weeks or months. Seedlings may tend to be somewhat spindly. Highly accelerated growth can result in stems with some kinks, whorled foliage, and other anomalies which will not be seen in an outdoor nursery. These are most frequently observed in the fall and winter. Unless they are extreme, all of these symptoms are normal during the exponential growth phase. This period ends when an acceptable percentage of the seedlings reach the desired shoot length.

17.3 Caliper Development and Cold Hardening

17.31 Caliper Development and Cessation of Apical Growth

To stop height growth and set buds, the plants are moisture stressed severely for a day or two at the wilting point, lights at night are turned off, temperatures are reduced, and the fertilizer regime is shifted from high nitrogen to low N high PK. The result of these steps is the onset of apical dormancy (section 15.3). The seedling continues to grow rapidly, but in caliper, bud development, and roots, not height. Needles may continue to elongate for a while. This growth continues until the nurseryman considers caliper, bud, and root development to be sufficient. Height and caliper growth of West Coast ecotypes is not easily separated and the procedure suggested here is most appropriate for the interior West.[1]

Induction of apical dormancy in the spring or summer may be difficult with some species, unless the photoperiod is artificially shortened using curtains. However, this problem can usually be circumvented by proper scheduling of the growing cycle. Normally, tree crops should be in germination and height growth periods in the spring and early summer (section 15.2). Details of the changes in the plant's environment to induce apical dormancy are included in section 15.3 dealing with growing schedule formulation.

The next step, when seedlings have adequate caliper, bud, and root development, is to harden the seedlings for winter or for transfer to the field for planting.

17.32 Cold Hardening

Before tree seedlings are subjected to an environment harsher than they are accustomed to, they must be hardened or acclimated, if damage is to be avoided. This is done by gradually exposing them to more severe conditions to bring about physiological changes that will enable the trees to tolerate the new conditions. To cold harden, turn off supplemental carbon dioxide enrichment and lower the temperature of the greenhouse to a little above freezing, and hold it there for about 5 weeks. The development of cold hardiness is progressive. Seedlings might endure a light frost after a week of 35°-40° F (1°-4° C) temperatures and severe freezes after 3 or 4 weeks of such preparatory conditions. After 6 weeks of temperatures down to 32° F (0° C), the trees are ready to take any subfreezing temperature common to their native environment. Remember that ecotypes cannot be conditioned to withstand freezing temperatures below what they are genetically coded to stand. Consequently, an Oregon Douglas-fir seedling will probably succumb to Great Plains winter temperatures, even if preconditioned carefully.

17.4 Movement of Trees to a Shadehouse

17.41 Strategy for Use of Shadehouses

Whether is is necessary to move trees to a shadehouse prior to shipping them is determined by the growing rotation developed for successive crops of trees utilizing a given set of greenhouses. (The general construction and attributes of shadehouses are discussed in section 8).

The shadehouse may be utilized as a management tool in three ways:

As a growing facility.—Trees are grown from seed there or are moved there from a greenhouse to complete their growth prior to shipment or the onset of winter weather. This strategy is most useful in mild climates. If used for the full growth cycle, the shadehouse may need to be rodent or bird proof.[2]

As a holding facility.—This usually means the growth objectives for the trees have been achieved in the greenhouse, and it is time to put another crop of trees into the greenhouse, but the previous crop has not been shipped. In these instances, the mature crop is held in the shadehouse, usually overwinter, until the planting sites are ready to receive it.

A combination of both.—A shadehouse may serve for both storage and growth depending on the crop rotations.

17.42 Biological Requirements for Movement to a Shadehouse

The seedlings must be in a physiological state that will allow them to successfully cope with the environment of the shadehouse, otherwise they will be

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[2] Personal communication with Dr. Peyton W. Owston, Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg., June 1978.

damaged or die. The idea is to transfer the seedlings outside into environmental conditions that approximate those previously encountered in the greenhouse or for which the seedlings have been conditioned in the greenhouse. If the transfer is made after the longest days of summer, and for some species, at any time, little added height growth should be expected. Actively growing trees usually may be transferred from the greenhouse to the shadehouse in summer without damage, but apical growth may cease once the interrupted night and warm night temperatures of the greenhouse are absent. Generally, growth in the shadehouse will be slower and, of course, very dependent on the length of the growing season remaining. Some species, such as coastal Douglas-fir, harden better if exposed to full sun than if shaded.[1]

The shadehouse should be rabbit-proof. In the fall, before the seedlings are mulched for the winter, poison bait should be placed under the containers and on the surface for rodent control.

17.43 Severe Weather Protection of Seedlings.

Trees moved to the shadehouse in late fall or winter must be cold hardy to successfully endure the low outdoor temperature. In areas of severe winter weather, the roots of the containerized seedlings may have to be protected by putting sawdust, peat, straw, or some other insulation around the groups of containers. Often, if container units are on pallets, they are removed and set flat on the floor of the shadehouse to increase thermal contact with the ground. The sides of the shadehouse should be left in place to reduce wind velocities over the seedlings and prevent winter burn. The trees should be shaded in the winter to reduce solarization and temperature fluctuation in the shadehouse. Because of the small volume of most CTS containers, moisture content must be watched closely both in summer and winter. In the interior West, accumulation of snow on seedlings in a shadehouse is usually beneficial and will not be detrimental, unless it becomes very deep (more than 2 feet or 60 cm). A moderate accumulation will help insulate the trees and prevent foliage desiccation from wind. This does not apply to West Coast ecotypes whose roots must not be allowed to freeze.[1]

17.44 Relation to Planting Site

Nurseries located at elevations lower than the intended planting sites frequently have problems keeping seedlings dormant until the planting sites are ready to receive the trees. Under such conditions, it may be necessary to move the seedlings either the previous fall or in the early spring from the nursery to a higher elevation holding area. This will assure that the seedlings will be dormant for spring planting at high elevations, so that they will not be damaged by frost following planting. This certainly adds handling and more costs, but it usually comes at a low workload period for foresters. It may be a small price to pay for long mild growing seasons at the nursery. An alternative is to put the seedlings in cold storage after they have hardened.[2]

17.45 Half-Way Houses

Where seedlings must be removed from the greenhouse to make room for another crop, protective "half-way house" structures are sometimes used. These are more sophisticated than shadehouses. Usually, they have waterproof transparent coverings, internal irrigation systems, and provision for supplemental heating to protect the seedlings during cold snaps. These protective units are used in Pacific Coast nurseries, primarily where sensitive tree species, mild weather, and cloudy skies make them practical. They are of doubtful value in the interior West, where high insolation rates, wide daily temperature fluctuations, and severe winter weather would make them uncontrollable.

SECTION 18.—DATA COLLECTION AND RECORDS

18.1 Cost and Productivity Data

18.11 Cost Data

18.12 Productivity Data

18.2 Mechanical Operation Data

18.21 Importance of Mechanical Operation Data

18.22 Mechanical Operations Records

18.3 Biological Data

18.31 Importance of Biological Data

18.32 Biological Data Records

18.33 Morphological Condition and Development Records

18.34 EC and pH Records

18.35 Foliar Nutrient Analysis Records

SECTION 18.—DATA COLLECTION AND RECORDS

The data collected in CTS operation is very important, because it can be used to maintain and improve the biological, mechanical, and economical efficiency of the operation.

18.1 Cost and Productivity Data

The CTS nurseryman's role is to grow quality containerized trees efficiently and economically. Both efficiency and economy of nursery operation can be measured by analysis of cost and productivity data. In the short run, the data tell:

1. Whether the budget is being overspent or underspent for a job, season, or crop.
2. What price should be placed on a given crop to avoid a loss or achieve a certain profit.
3. How materials and labor costs change from one year to the next.
4. How efficiently a certain part of production process was executed, and if recent modifications resulted in an improvement over the previous year.
5. If a certain machine is too expensive to operate.

In the long run, such data will tell:

1. Whether business trend is profitable and the business is growing.
2. About trends in costs of material or labor, which may indicate major changes in the operation are needed.
3. If certain machinery is worn out and should be replaced.

18.11 Cost Data

Cost data should be accumulated on each part of the CTS growing process. This way the total cost of the trees produced is known and can be recaptured in the price, and the cost of each part of the production process can be assessed.

Bookkeeping and accounting methods are well established. These vary in sophistication from simple ledgers to computerized systems with instant recall. Small operations require only simple methods; large, complex operations need more sophisticated methods. Many consultants are available in this field.

Cost data is an indirect indication of work productivity, because labor time can also be converted to monetary terms. This is very useful when comparing labor and material costs. When comparing labor productivities, it is best to compare times to do the same job.

18.12 Productivity Data

Productivity data can be accumulated on the various operations in a CTS operation. Different ways to employ labor in a given operation can be evaluated in terms of output per unit labor input. The nurseryman can then select the alternative providing the most efficient use of labor. Also, the amount of work to do a given job and its cost can be weighed against the cost of acquiring new machines.

Productivity data, as time to do a job, are a direct measure of labor utilization efficiency. If a job is taking 5 minutes per unit for five workers, and reorganization of the effort reduces the time to do the work to 4 minutes or requires one fewer worker, efficiency has been increased. The only tools needed for productivity assessment in simple operations are a watch and a scratch pad. More complex operations may require timeclocks and job category coding.

Management and supervisory impacts on productivity can also be evaluated by relating output to intensity of supervision.

18.2 Mechanical Operation Data

In this context, mechanical operation data refers to records of the function of greenhouse systems. These include hygrothermograph charts of temperature and humidity, records of frequency of operation of greenhouse heating and cooling equipment, records of electrical conductivity and hydrogen ion concentration in irrigation solutions, and a diary of observations.

18.21 Importance of Mechanical Operation Data

Such information tells how well the mechanical system of a greenhouse is working. Evaluation of these data allows the nurseryman to:

1. Compensate for changes in the outside climate which the greenhouse system cannot do by itself.
2. Locate mechanical trouble spots before the crop is seriously affected.
3. Relate abnormal crop condition to mechanical malfunction of the greenhouse system.

18.22 Mechanical Operations Records

Records of temperature and humidity usually consist of charts from hygrothermographs. These instruments are discussed in section 6.56. Larger operations sometimes have instruments that record readings from several remote temperature or humidity sensors. Data are usually recorded on a scroll of paper. In very large installations, data may be recorded by computer.

Records of equipment sequencing and operation can be recorded by a voltmeter or photorecorder (for light systems). Sophisticated systems recording the phase or stage of operation are available but seldom are justified in CTS operations.

Records of pH and EC of the irrigation solution are usually logged in a daily diary of greenhouse operation by a technician. A method of charting these readings, both for the irrigation solution and the leachate, is discussed in section 18.3.

Weather records from the area around the greenhouse are necessary to interpret greenhouse system function. Unusual outside conditions are often the cause of aberrations in internal temperature and humidities. Greenhouses are designed for a site on the basis of weather averages, not the rare extremes.

18.3 Biological Data

Biological data are derived from the crop itself, such as physical measurements and observations of the trees such as height, weight, and foliar nutrient analysis.

18.31 Importance of Biological Data

These factors are very important to the nurseryman, because they provide a measure of the well-being of the crop, they provide a standard for the progress of the crop and the quality of the culture being practiced on it, and they show the relationship between crop progress and the mechanical operation data (section 18.2). In other words, these measures tell the nurseryman how well the crop is doing and what he might do to make it better.

18.32 Biological Data Records

Format and methods for keeping biological data records for CTS operations are not standardized at all. At the very least, some notes are kept of abnormalities observed in the crop. However, since there is no established system for this recordkeeping as there is for cost or mechanical operation data, some suggestions are provided based on experience, observations, and logic.

18.33 Morphological Condition and Development Records

The progress of the crop should be recorded, along with observed abnormalities that occur. This should be done on a systematic, daily basis, as a "logbook" of crop progress. Notes on mechanical problems with the greenhouse system should be included, because crop responses are directly related to the functioning of the mechanical system. The logbook should also include notations on cultural activities as they take place. Anything unusual, such as severe weather conditions, should be noted. The logbook serves two very important purposes.

First, it provides a day-to-day record and serves as the prime record of the crop development. Therefore, if anything goes wrong with crop progress, it is the first place to look for clues to the cause. Also, it serves as the model for future culture. Things that work well can be duplicated; things that do not can be abandoned. Duration of the growth stages serves as the basis for changing the timing of the growing schedule.

Second, the logbook makes the greenhouse operator accountable. If forced to enter activities and observations, he is more likely to do the work right and be observant. Performance can be reviewed by the supervisor on an intermittent basis by reviewing the logbook. Certain activities should always be noted and be scheduled events. These should include: fertilization, checks of mechanical functioning of greenhouse equipment, seedling measurements, observations on seedling condition, and outside weather. Sophistication of these records should vary with the operation. Plotting growth rates on charts of crop development would allow easy· comparisons of crop progress from year to year. This comparison might alert a nurseryman to incipient problems.

18.34 EC and pH Records

Both these readings are indirect indications of what the pH and EC of the soil solution in the growing medium is, because they are made on a leachate of that solution (sections 6.56 and 13). The importance of the reading is mainly in the trend they express over a period of time. Any large change from one reading to another would indicate a serious equipment malfunction. A chart can display trend and large changes visually, without the need to scan a long list of numbers. Figure 18-1 portrays a suggested chart. The vertical axis has both pH and EC units. The range of the units for pH and EC should be wide enough to encompass the normal range to be expected but not much more. This allows for good vertical separation of readings, so, the differences between the applied solution and the leachate are readily apparent as are differences from time to time.

The horizontal axis is time in days. The width between day points should be great enough so that a difference in measurements 2 or 3 days apart is apparent. EC and pH readings for both the irrigation solution and the leachate are marked on the chart at each irrigation. The latest points should be connected with a straight line to the last point for that reading. The line for each measure should be color coded. This should develop four lines on the chart, one each for leachate EC, irrigation solution EC, leachate pH, and irrigation solution pH. The relationships between these readings and the implications of the trends they portray are discussed in sections 13.3 and 13.4. Display the chart where it can be scanned without having to get it out of a drawer or file. This way, it is constantly available for quick visual checks. It also immediately shows the manager if the recorded data is up-to-date.

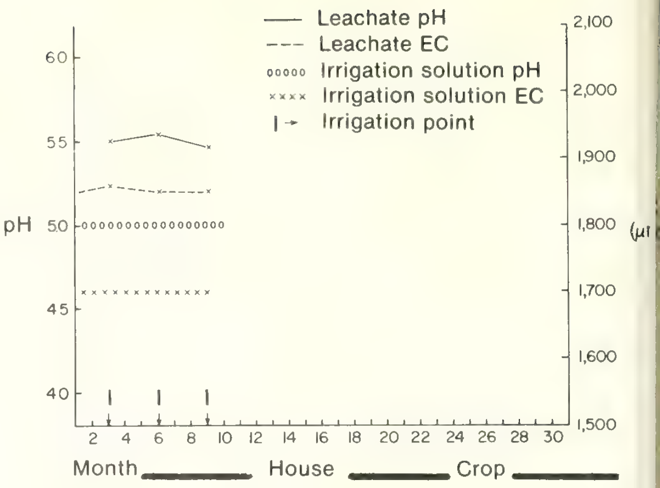

Figure 18-1.—Leachate EC and pH record chart.

18.35 Foliar Nutrient Analysis Records

Foliar nutrient analysis usually takes place after the crop is well into the growing schedule and sufficient mature foliage is available for testing. The best nutrient levels for a given state of development are often in doubt (section 13.52), but if a crop is normal in appearance and growth rate, the foliar nutrient levels in it become the target or "norm" for next year. Several years records represent the best information available. Effects of cultural changes can be weighed in light of changes in foliar nutrient levels from this norm. The importance of these records is long term.

SECTION 19.—GREENHOUSE MANAGEMENT AND SUPERVISION

19.1 Definition of a Greenhouse Manager

19.2 Principles of Greenhouse Management Success

19.21 Greenhouse Cleanliness

19.22 Clear Managerial Goals

19.23 Relating to the Crop

19.24 Commitment to the Operation

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SECTION 19.—GREENHOUSE MANAGEMENT AND SUPERVISION

19.1 Definition of a Greenhouse Manager

Nelson (1973) defines a manager as: "an organizer, a planner, a person capable of great capacity for work, a decision-maker, a diplomat, a problem solver, a firm believer that all activities must be for the betterment of the business, a person of good judgment, and one who is knowledgeable, honest, and forthright, and challenged by the accomplishment of the job."

It is rare to find all of these sterling qualities in one person, but the definition illustrates the multifaceted nature of the manager's job. The manager must be honest and be able to think and reason. Problems will arise that will require solutions that can only be arrived at by careful analysis and deduction. The CTS nursery manager must know something about greenhouses, trees, and the economics and management of business or government enterprises. He must know enough about these things and have sufficient intellect and self assurance to handle business management procedure, personnel management, physical facility management, crop rotations and scheduling, seedling culture, marketing, and delivery. If the nursery is part of a large organization, staff and other managers may share these loads and help with these jobs. However, the nurseryman must see that overall management is coordinated.

19.2 Principles of Greenhouse Management Success

19.21 Greenhouse Cleanliness

Greenhouse cleanliness is essential. The cheapest insurance against disease, insect, mechanical, or seedling physiological problems in a greenhouse is to keep it clean and in good order. Not only is cleanliness advised for sanitation, but it is good business management. It is much easier to sell seedlings to potential tree buyers or potential supporters within the organization, if the operation is clean, orderly, and well manicured. These visitors equate a clean, neat operation with efficiency and good management; this usually proves to be correct.

The emphasis on cleanliness, neatness, and maintenance also affects the nursery workers. By emphasizing these things, management indirectly indicates, "we care about this place; it reflects on you as well as us; it is going to be something we can all be proud of." Under these conditions, workers, especially long timers, will respond with added pride in their work and feel they belong and have a stake in the place.

19.22 Clear Managerial Goals

The mission of the nursery must be kept foremost in the manager's and workers' minds. An example might be, "to grow high quality seedlings at a reasonable cost." Often, nursery expansion activities, maintenance work, preoccupations with economy, and interest in other activities, such as tree improvement, can unwittingly override the prime reason for the operation. This is often directly attributable to management emphasizing supplemental activities without providing adequate support, monetarily, technically, or in personnel, to avoid compromising the prime goal of the unit.

19.23 Relating to the Crop

The manager and his staff must learn to "think like trees." They should view nursery activities from the standpoint of how the tree seedlings will react. The goal at the nursery usually is to grow good trees on a reliable basis. This cannot be emphasized to the crew enough. The crew should have at least a rudimentary knowledge of the effects that their activities will have on the tree seedlings. In recent years, the American Association of Nurserymen has been emphasizing basic horticultural trainning for nursery workers. This training not only gives more meaning to the work they do, but an appreciation of the effect of their activities on the plants being grown. Such education will often prevent disastrous errors on the part of CTS greenhouse workers who, for instance, might not understand the biological implication of turning down the heat, because it is too hot to work comfortably. However, in the final analysis, the manager is the prime trainer of the crew. His knowledge and attitude toward the CTS crop will largely determine how well the crew learns to "think like trees."

19.24 Commitment to the Operation

To successfully operate a CTS nursery, someone always has to care about it. Trees that lapse into apical dormancy may not begin shoot growth again until the following year. This means the crop will be a year late, and its prolonged occupation of the greenhouse may preclude sowing the next crop. A house full of dead, damaged, stunted, dormant, or otherwise compromised tree seedlings usually results when there is no one who conscientiously looks after the trees and the functioning of the greenhouse all the time.

Growing trees in a greenhouse allows control of the environment, so, it is optimal for seedling growth. This is a great advantage, but at the same time, the greenhouse manager takes on added responsibilities for the well-being of the crop that the conventional nurseryman does not. Nature provides buffers against plant damage in the natural environment. These include reserve water holding capacity in soils, soil buffering of chemical changes, and late summer conditioning of plants for cold weather. The CTS nursery operator is protected by few of these natural buffers. When a container dries out, no rain will water it. If the irrigation water is too acid, the soil will not neutralize it. So, the CTS nurseryman has mechanical advantages that can lead to very rapid tree growth, but there is little room for error. The price of rapid CTS growth is knowledge and vigilance.

Many people have the idea that a nursery can be run at half or full throttle like a factory with one of two production lines shut down. To a limited extent this is true, but the proper conditions for growth must always be maintained in a greenhouse, even if it is half full.

19.25 Unity of Command

Raising trees in containers is not simple when done right. Consequently, because the nurseryman is knowledgable and held responsible, only he should direct nursery activities and make changes in schedules and control settings. In all CTS nursery operations where there has not been a clear assignment of responsibility, the operation has run into trouble. The nurseryman needs a clear assignment of responsibility together with authority to carry it out. When he sinks or swims on the strength of his own actions, the result is usually good trees.

19.26 Technical Competence

Traditionally, forest tree nurserymen have come from the ranks of the forestry profession. There are good reasons for this, not the least of which is that foresters with field experience know how difficult tree planting is and how important it is that each tree be a good one. These foresters, serving as nurserymen, assistant nurserymen, or trainees, learned to grow tree seedlings in conventional nurseries by observation, trial and error, and study of various publications on the subject. While this mechanism for producing forest tree nurserymen has been viewed with disdain by some horticulturists, researchers, and other segments of the botanical community, the process has developed a stable, if small, core of able professional forest tree nurserymen, who are currently producing more than one billion forest tree seedlings per year in the United States.

At present, more CTS nurseries are being constructed than there are forest tree nurserymen to manage them. This deficit is being ably filled by horticulturists. The requisite for a CTS nurseryman is that he understands and is able to grow tree seedlings regardless of his background. He must have the knowledge from education on the job or in school to understand how trees react to cultural treatment. This does not mean that he has to be a forester, horticulturist, or botanist.

The nurseryman must be allowed to grow the trees. Too often, he is buried in administrative detail, because he is the ranking manager at the nursery. This is a waste of resources and poor management. Adequate support staff must be provided to allow the nurseryman to do the job he is hired to do.

SECTION 20.—GREENHOUSE PEST MANAGEMENT

20.1 Principles of Pest Management

20.11 Facility Design and Sanitation

20.12 Natural Controls

20.2 Pesticide Use *

20.21 Identification of the Pest

20.22 Pesticide Safety

20.23 Pesticides Used in CTS Greenhouse Operations

20.3 Types of Pests

20.31 Weeds

20.32 Rodents

20.33 Insects

20.34 Diseases

SECTION 20.—GREENHOUSE PEST MANAGEMENT

20.1 Principles of Pest Management

Control of pests in a CTS greenhouse is a constant challenge. Several types of control procedures are available.

20.11 Facility Design and Sanitation

Pest control really begins with site selection and physical plant development. The site should be well drained and away from other crops. Work areas should be easy to clean. There should be gravel or a hard surface outside the greenhouses to prevent weed growth and tracking soil into the greenhouse.

The greenhouse and work buildings should be designed for easy cleaning. Storage areas should be adequate in size and neat. The greenhouse should provide continuous internal forced air circulation (Averre 1975). It should be able to hold relative humidities below 90%, except when irrigating, and near 70% most of the time. The watering system should be designed to apply water at as high a rate as the crop will stand to minimize the time the seedling foliage is wet.

All greenhouse hardware, benches, hand tools, containers, and floors should be clean and disinfected before introducing a new crop of trees. Solutions of 1% sodium hypochlorite are effective and convenient for large areas. Hand tools can be cleaned with the same solution or 70% denatured alcohol or 5% formaldehyde. All hardware and equipment should be kept as clean and sanitary as possible all the time. However, fumes from some disinfectants, such as formaldehyde, are toxic to plants. So, these must not be used in the greenhouse while plants are being cultured.

The greenhouse structures should be tight to minimize entrance of animals, insects, or disease organisms. Where insects are serious pests, air intakes may have to be screened. All doors should be screened and have automatic door closers on them. Irrigation water from surface sources should be filtered (section 4.15). Pruned or thinned parts of plants should be removed at the end of each day's work.

Rotation of plant species in a greenhouse from crop to crop is recommended to prevent pest buildup. A period of non-use of the greenhouse is also recommended, but frequently neither rotation nor non-use is practical.

Turf, gravel, asphalt, or cement (not bare soil) should be used around greenhouses. Soil can be tracked into the greenhouse. Also, blowing dust can be sucked into greenhouse ventilators and contaminate the crop.

Every effort should be made to control weeds in and around the greenhouse. Weeds may harbor insects, disease, and animal pests. Vegetables or ornamental plants should be kept away from the greenhouse because they often harbor pests. Vegetative or animal refuse should never be allowed to accumulate around a greenhouse. This includes leaves from ornamental trees and grass clippings. Many fungi and insects overwinter in such material. The best disposal method is burning or burying in a sanitary landfill.

Remove all trees harboring known pathogens of crop seedlings from the vicinity of the greenhouse.

This is particularly important for diseases spread by airborne spores. For instance, oaks harboring fusiform rust fungus should not be near greenhouses growing loblolly or slash pines. Pines with western gall rust should not be near greenhouses growing ponderosa, lodgepole, or other susceptible pines. Do not permit any non-crop plants in the greenhouse. These form a reservoir of disease and insects of many kinds (section 19.21).

20.12 Natural Controls

In some instances, pests can be controlled by their natural enemies. The best example is reduction of rodents around greenhouses by a cat. Ladybird beetles feed on aphids. The practical applications of such natural controls are limited but growing.

20.2 Pesticide Use

Pest epidemics are best avoided, not treated. CTS nurserymen can go to great lengths to avoid pest problems and still be better off than having to control them with pesticides. Most pest problems in CTS operations are due to poor greenhouse design and operation, or lack of sanitation or exclusion practices. However, when certain tree species are grown or greenhouses are in certain climates, the need to control certain pests is unavoidable. Preventative measures, such as chemical applications, should be used before damage occurs, when it is nearly certain the target pest will be encountered. Otherwise, see-and-treat procedures are best. The nurseryman must be observant and alert in order to notice the presence of pests before serious damage is done.

20.21 Identification of the Pest

Once a pest is noticed in a CTS greenhouse, it must be accurately identified. Proper identification allows prescription of the best pesticide to use, the best formulation, the best application method, and the best time and frequency of application. The best treatment minimizes human exposure while maximizing control of the pest. The greenhouse operator should carry with him a 10X hand lens for close examination of damage symptoms. Many times, problems can be diagnosed on the spot, even by personnel with limited experience. If expert technical assistance is required to make accurate pest identifications and prescribe the treatment, assistance can be requested from a variety of sources including the state department of forestry, the state department of agriculture, the Agricultural Extension Service of the state university, and the Forest Insect and Disease Management Section, State and Private Forestry, Forest Service, United States Department of Agriculture.

Several steps have been listed to help diagnose tree seedling pests (Peterson and Smith 1975). Observances of these steps by nurserymen will expedite diagnosis by an expert.

1. Determine as accurately as possible the part of the plant affected. Death, or damage to only needles, indicates a needle disease or needle mining or defoliating insect; death or damage of the stem and/or branches indicates a canker disease. Death of the whole tree indicates a root disease or drought. Note the pattern of damage in the seedlings. Is it limited to the south side? To the lower crown?
2. Note what tree species are affected.
3. Note the pattern of occurrence. What areas of the greenhouse show the problem most severely? How do these areas differ from those areas free of the problem? Are these areas related to any cultural activity, irrigation pattern, structural feature?
4. If the cause of the damage is not immediately evident, look first for obvious causes, such as animal damage, waterlogged growing medium, high salt concentration in the soil solution, improper fertilization leading to nutrient deficiencies or toxicities, excess humidity or heat (check hygrothermograph charts), etc.
5. Can insects be seen with or without a hand lens? Can fruiting bodies, or mycelia of a disease organism be seen? Note shape, size, color, and other features, if all or part of an organism that may be the pest can be seen. Observe accurately, and try to judge whether the organisms found are the main cause of the trouble or just secondary.
6. If the whole tree is dead or unhealthy, and nothing is found above ground to indicate the cause of the damage, expose the roots for examination.
7. If still unsure, learn or record the recent history of the problem in the greenhouse. Does it occur in other greenhouses in the area? When was it first noted? What cultural practices have been used on the crop? Can these be related to the injuries?
8. Record all of the information before contacting an entomologist or pathologist. Experts can't help without information. Samples of damaged trees are usually most helpful, and should be as fresh as possible. Refrigerate samples if possible.

When the pest is identified and treatment with a chemical pesticide is prescribed, the chemical should be promptly applied exactly as specified. The careless use of pesticides by inexperienced workers sometimes cause more damage to the crops than the target pest.

20.22 Pesticide Safety

Pesticides must be used safely. Some are highly toxic to humans. The degree of toxicity is usually stated on the label of the container, but it is best to treat all pesticides with the respect due any poisonous material. Numerous lists of precautions are available. The following one is from the Entomological Society of America (1975):

1. Store all pesticides in original containers and in a locked cupboard or closet where they are out of the reach of children, pets, and livestock.
2. Keep all pesticides away from food or animal feed.
3. Use pesticides only when necessary, and be sure to use the correct material for the job.
4. Read the entire label on the pesticide container and follow instructions and precautions exactly. Application of a pesticide in a manner not consistent with its labeling is a violation of federal law.
5. Avoid inhaling sprays or dusts when mixing or applying them.
6. Avoid spilling pesticides on skin or clothing. If spilled, wash off at once with soap and water. Clothing wet with spray chemicals should be removed at once. Particles or drops of pesticides which may accidentally get into the eyes should be flushed out immediately with large volumes of clean water.
7. Do not eat or smoke when working with pesticides. Wash hands and face and change clothing after handling pesticides; wash contaminated clothing daily.
8. Discard any pesticide container without a label or with a damaged label. Do not guess at contents. Be familiar with Title 40, Chapter 1, Environmental Protection Agency Post 165 "Regulations for the Acceptance of Certain Pesticides and Recommended Procedures for disposal and Storage of Pesticides and Pesticide Containers."[1]
9. Don't allow spray or chemical dusts to drift onto adjacent crops or fields. Cover feed and water containers in livestock areas if there is any danger of contamination.
10. Wear protective masks and clothing, if so directed on the label.
11. Use pesticides only at the recommended dosages and timing.
12. Destroy all empty nonreturnable pesticide containers. Break or puncture glass or metal containers to prevent reuse. Incinerate paper or cardboard containers (avoid coming in contact with the smoke) and bury all ashes, unburned residues, and broken containers in a sanitary land fill (item 8).
13. Use clean, properly functioning equipment to apply pesticides. Fill and clean application equipment where the rinse water or spills will be absorbed into the earth without polluting nearby streams or ponds or harm crops or animals.
14. If symptoms of illness occur during or after spraying or dusting, call a physician or get the patient to a hospital immediately.

20.23 Pesticides Used in CTS Greenhouse Operations

The registration and use of pesticides are regulated by law. These include several federal laws, regulations, and acts and various state pesticide control laws. The major federal legislation is the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which is administered by the Environmental Protection Agency. This law makes it illegal to use a chemical pesticide in any way other than that specifically labeled on the container. The chemical pesticide registrations and labels are being continuously reviewed and amended. Therefore, any specific recommendations in this manual as to what pesticides may be used against specific pests should be checked to be sure they are legal.

Table 20-1 lists fungicides for disease control, and Table 20-2 lists insecticides in current use. Because of frequent changes in federal and state laws, the CTS nurseryman should consult his state agricultural chemical coordinator in each instance before purchasing or using any chemical.

20.3 Types of Pests

20.31 Weeds

In CTS operations, where sterile growing media are used and tree seed is weed free, weeds in the containers are not a problem. Weed seeds can be drawn into the greenhouse through the ventilation system or carried in on workers' feet. This can be minimized by controlling weeds close to the greenhouse and through proper sanitation. The weed seeds introduced into the greenhouse will germinate in the containers or on the floor. Those that germinate and grow in the containers can be removed by hand. If the growing medium is free of weed seeds, weeding of containers will be minimal. Greenhouses with gravel floors can develop a considerable growth of weeds on the floor. This is not only unsightly but also unsanitary. These weeds may harbor other pests. Because the weeds develop between and under benches, they may be hard to control manually. The gravel floors

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[1] *Federal Register, Vol. 39, No. 85, May 1, 1974.*

Table 20-1.—Fungicides for disease control (Powell 1975).

Disease	Chemicals for control	Remarks
Damping-off and cutting rots	PCNB (Terraclor) (1), Diazoben (Cexon) (2), ethazol (Truban, Terrazole) (3) Captan (4)	(1) For rhizoctonia only. (2) and (3) for pythium and phytophthora only.
Water mold, root rots	Diazoben (Dexon), ethazol (Truban, Terrazole), Captan	
Other root and stem-rotting fungi	benomyl (Benlate)	
Leaf spotting fungi	benomyl (Benlate) (1), Chlorothalonil (Daconil, Termil) (2), Captan (3), maneb (Manzate D, Dithane M-22) (4), Mancozeb (Fore, Manzate 200) (5), ferbam (Fermate, carbamate) (6), zineb (Parzate C, Dithane Z-78) (7), folpet (Phaltan) (8), fixed copper or Bordeaux mixture (9)	(1), (2), and (3) for botrytis control; (3) through (9) for other diseases; check labels for specific information. Copper may cause plant injury.
Rusts	Zineb, ferbam (Fermate, Carbamate), mancozeb (Mantzate 200, Fore)	Frequent application generally necessary with all these materials.
Powdery mildews	benomyl (Benlate), cycloheximide (actidione PM), dinocap (Karathane), sulfur	Frequent application and good coverage essential. Cycloheximide and sulfur may cause plant injury.
Bacterial diseases	streptomycin (Agri-Strep), fixed coppers or Bordeaux mixture	Both materials may cause plant injury.
Nematodes, soil	Aldicarb (Temik), DBCP (Nemagon), oxamyl (Vydate L)	Highly toxic materials, use caution.

Table 20-2.—Insecticides for greenhouse pests (Pirone et al. 1960).

Type of insect	Chemicals for control	Remarks
Thrips	malathion, dieldrin, lindane, parathion, Sulfotepp	Apply malathion and lindane frequently.
White Flies	Pyrethrum, rotenone, nicotine sulphate, malathion	Pyrethrum, rotenone and nicotine sulphate control nymphal stage.
Scale	malathion best, nicotine sulphate and soap	
Aphids	nicotine sulphate and soap, lindane, malathion, Sulfotepp, parathion, Thiodan	nicotine sulphate on warm days only; do not apply parathion before or after sulfur.
Mites	sulfur, Aramite, Dimite, Kelthane, Ovex, malathion	

of greenhouses can be treated with herbicides. Be sure to select non-volatile broad spectrum herbicides such as Hyvar X® or simazine and apply them so that the tree seedlings are not contaminated. Be sure the herbicide is registered for that use (Whitcomb and Santelmann 1976).

20.32 Rodents

Exclusion of rodents from the greenhouse is important. The principal pests are mice, which can eat or cache large numbers of seeds from containers in a short time. They will also clip young succulent seedlings. The main defenses are construction of physical barriers, minimizing suitable habitat surrounding the greenhouse, and trapping or baiting. Areas around the greenhouse should be clean and free of debris or plants that will shelter or provide food for rodents. The greenhouse should be tightly constructed at the base, and all doors should automatically close when released. Elimination of habitat for mice, combined with barriers to greenhouse entry, will usually prevent serious rodent problems. Some limited trapping or baiting may be necessary, however. Warfarin® as treated oat bait is the most commonly used rodenticide at present. Keeping a cat or two around a nursery complex also helps hold rodent populations in check.

20.33 Insects

Many common insect pests, such as ants and caterpillars, are not serious pests in CTS culture. They can usually be controlled by sanitation, barriers, and baiting. Usually, serious insect pests enter the greenhouse through the ventilation system. Under greenhouse conditions, these insects can reproduce rapidly and cause extensive damage. The most bothersome are aphids, whiteflies, scales, thrips, and mites. Large insects occur less frequently. They are more obvious, and are easier to identify and control.

Whiteflies.—The greenhouse whitefly *(Trialeurodes vaporariorum)* is a sucking insect which secrets masses of honeydew. Black sooty mold develops on this sticky substance. At average greenhouse temperatures, whiteflies complete a generation in 3 to 4 weeks (Sorenson 1975). The whitefly nymphs are pearly white and are attached to lower leaf surfaces. Adults are small pure white flies that dart away swiftly when the leaves are disturbed (Pirone et al. 1960).

Thrips.—Thrips *(Thysanoptera)* are very minute insects that are often wingless, even when mature. They rasp the tissues of plants and suck the sap. This causes leaves to curl and become deformed. The damaged areas have a silvery or glassy appearance. A hand lens or low powered dissection microscope is useful for identifying these insects.

Aphids.—Aphids belong to the order *Homoptera,* as do whiteflies, mealybugs, and scale insects. Aphids have a complex reproduction cycle, which involves the production of a series of generations without fertilization. Many aphids, mealybugs, and scale insects cover themselves with a white waxy secretion, under which the young develop. The secretion of honeydew by aphids, whiteflies, and scale insects may result in growth of unsightly black molds on surfaces of leaves and stems. *Homoptera* are often carriers of viruses of several destructive plant diseases (Pirone et al. 1960). Aphids are soft-bodied, small, sluggish, gregarious insects that multiply rapidly. They are usually green or white.

Scale insects.—Scale insects form a waxy, hard, white, gray, or black secreted shell over themselves. This shell adheres to the plant.

Mites.—Mites are small spider-like animals that suck the juice from the tender growing points and leaves. Greenhouse plants are especially susceptible to attack. Mites are only about 1/50 inch (½ mm) long and may be green, yellow, or red. Leaves usually assume a gray or yellow cast when severely infested and may be occasionally covered with fine silken webs. Mites complete a generation in 9 to 10 days and often pass unnoticed until severe damage results.

A well planned insect control program can prevent insect damage in a greenhouse. Preventive control is easy. Eradicative control should be used only when needed. Plants such as potatoes, tobacco, milkweed, plantain, chickweed, catnip, groundcherry, horsenettle, and jimson weed, should not be grown within 150 feet of the greenhouse (Sorenson 1975), because they serve as hosts for insect pests. The area around the greenhouse should be clipped lawn, crushed rock, etc. The greenhouse should be kept free of debris. Regular inspections should be made to look for insect pests. Greenhouse doors and air intakes should be screened.

If harmful insects are present, eradicate with approved insecticides. In most cases, some limited use of chemical controls is needed despite the most careful avoidance measures. If management is alert and observant, the see-and-treat program should be best. The mode of application and chemical used should be designed for the target insect. Timing the application is also very important to achieve optimum effectiveness.

The greenhouse manager should seek help in identifying pests unless he is very certain of the identification. Various state extension specialists are available for consultation. They can also recommend chemicals, formulations, and application methods. Expert and up-to-date assistance in this area of greenhouse operation is vital.

In recent years, the use of agricultural chemicals for pest control has been increasingly regulated by environmental protection legislation. Most older textbooks on diseases and pests of plants contain specific recommendations on chemical use. Such lists itemized the best and most effective chemicals available at the time the books were written. Many of these chemicals are no longer available, or restrictions have been placed on their use. Therefore, it is best to consult knowledgeable people before selecting a pesticide.

Some of the currently registered insecticides are: malathion, Thiodan®, naled, mevinphos, nicotine sulfate, parathion, metaldehyde, dichlorovas, lindane, Tedion®, and calcium cyanide. Each of these chemicals must be used in accordance with the pesticide label on the container. In general, soft-bodied insects can usually be controlled by sprays of malathion, nicotine sulfate, or lindane. Scale insects should be sprayed when they are crawling. Application timing and rate should be determined from the label and expert advice. Care must be taken to be sure the chemical is not phytotoxic. Generally, if repeated applications are needed, it is best to rotate applications of the various chemicals, to avoid build-up of pests tolerant of any single chemical.

Malathion and difocal (Kelthane®) are effective against mites. If the mites become resistant to the miticides, combinations or rotating applications of the effective chemicals may be best. Lindane is effective against moth and sawfly larvae.

20.34 Diseases

Peterson (1974) summarized the most common disease problems encountered in CTS operations.

Grey mold fungus *(Botrytis cinerea)*.—Grey mold has caused higher losses in CTS facilities than any other pathogen. Most forest tree seedlings are susceptible. Grey mold is almost universally present on dead and dying plant material. It usually spreads from dead parts of the host to healthy tissues, but can infect healthy tissue directly. The infected tissue first turns light, then dark brown and eventually becomes covered with fine grayish-brown powdery growth. Infections are usually first seen on the lower needles and old juvenile bracts.

The disease is likely to occur when humidity is high or surface moisture is present for long periods in the greenhouse. This occurs when:

1. The growing medium is poorly drained and a high humidity persists at the surface of the container.
2. There is extended high humidity in the greenhouse due to lack of ventilation and air mixing or watering at low application rates.
3. The outside humidity and temperature are high, which makes it very difficult to cool and dehumidify the greenhouse.
4. Dead plant matter is present in and around the seedlings.
5. Seedlings are large and lush which keeps their lower crowns in deep shade.

The best preventive measures are to avoid these circumstances. Keep greenhouse humidities at an average of 60-70% relative humidity as much of the time as possible by ventilating the greenhouse, providing good air circulation around plants, and watering as rapidly as the seedlings and pot mix will tolerate. Irrigate during the warmest time of day and then ventilate. The greenhouse should be kept free of dead plant matter, and the growing medium should be well drained. Leaky valves and nozzles should be immediately replaced. The greenhouse floor should be well drained and should dry rapidly following irrigation. With these precautions, grey mold may never be a problem. However, if it does develop, benomyl (Benlate®) is probably the safest and most effective fungicide available at this time, although some resistance has been demonstrated. To avoid development of resistance it is best to alternate fungicides. Some of these chemicals reduce growth in some tree species, so, expert advice from an experienced plant pathologist is recommended (Low 1975).

Most fungicides act as protectants and do not cure the disease once it is in the plant (Smith 1975). Therefore, fungicides should be applied at the first sign of the disease. Applications should be continued as long as the disease persists. Where climatic conditions favor grey mold or species are grown that are particularly susceptible, a regular fungicide treatment program may be required from the start of the crop. Applications of fungicide may be needed as frequently as every 2 weeks. Such applications on a regular, preventive basis should not be necessary in well engineered and operated greenhouses in the interior West and Great Plains, because relative humidity of the air is normally low. In contrast, high humidity conditions on the Pacific Coast have made regular preventive fungicide applications necessary in some instances.

Damping-off.—Fungi such as *Pythium, Rhizoctonia, Phytopthora,* and *Fusarium* are common in CTS culture. Only very young seedlings are attacked. As soon as stems begin to lignify, 3 to 4 weeks after germination, the incidence of disease declines rapidly. Early attacks on the seed radicle prior to seedling emergence are called "pre-emergence damping-off" and may go undetected. Post-emergence infection generally occurs at or just below the root collar. A water-soaked or necrotic lesion develops. In conifers, this tissue collapses and the seedling falls over. Hardwoods usually remain upright, gradually wilt and break off (Filer and Peterson 1975).

The key to preventing damping-off in a CTS greenhouse is avoidance. Use a well drained growing medium, and do not introduce nitrogen into the soil solution until germination is completed. The greenhouse and containers should be clean, the growing medium should be sterile, and the seedcoat should be free of spores. If an acid peat-vermiculite or perlite growing medium is used, it is usually nearly sterile. If damping-off problems are encountered and seed coat contamination is suspected, the surface of the seedcoats may be sterilized by a short soak in concentrated hydrogen peroxide solution followed by a thorough rinsing in clean water (Riffle and Springfield 1968, Barnett 1976). The tolerance of different tree seeds to this treatment varies, so, germination tests should be conducted for treated and untreated groups of seed, unless the technique is well documented for the species. There are other methods of seed coat sterilization such as soaking the seeds for 30 minutes in mercury bichloride solution (Pirone et al. 1960).

Seeds can also be coated with fungicides such as Captan® or Thiram®. There is conflicting evidence about the suitability of some of these materials, since adverse effects on seed germination have been reported (Peterson 1974, Denne and Atkinson 1973, Low 1975, Aldous 1972).

Fusarium root rot *(Fusarium oxysporum).*—This fungus has been isolated from a number of CTS nurseries as an agent of seedling mortality (Landis 1976). This and some other species of *Fusarium* are responsible not only for damping-off in young seedlings, but also root rot of older seedlings. Affected seedlings show root dieback and the formation of corky black tissue over yellow-brown dead vascular tissue of the roots. The tops become stunted, wilted, and chlorotic, and most seedlings eventually die. Those that live and are shipped do not survive as well in the field, although studies in the western United States indicate *Fusarium* disappears in 3 to 4 years from the roots of outplanted seedlings that survive (Smith 1975).

Cultural methods have not been effective in controlling this disease (Smith 1975). Recently, benomyl used as a soil drench has shown promise, because it moves systemically within the tree (Pawuk and Barnett 1974). Drenches with other fungicides are sometimes effective in controlling *Fusarium.* These include Captan® and Truban®, but these fungicides, as well as benomyl, may retard seedling growth when added to the growing medium. Consequently, they should be used only when there is an identified need.

As with other greenhouse problems, sanitation will help prevent root rot. Use a growing medium that does not waterlog, do not overwater, and keep adequate air circulation under the containers. Be especially vigilant if the containers are placed on the ground to overwinter them.

Other diseases.—Other diseases have rarely been serious problems in CTS greenhouses. However, the greenhouse environment is very amenable to many pathogenic organisms, and diseases can spread with lightning speed in such environments. The nurseryman must constantly watch for any changes in seedling appearance. Insect and disease infestations must be detected, the pest identified, and control measures instituted as rapidly as possible. Most of the discussion in this section has related to conifer tree seedlings. Hardwood seedlings host many more pathogens and even greater vigilance is required during their culture.

SECTION 21.—TROUBLESHOOTING CTS NURSERY PROBLEMS

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SECTION 21.—TROUBLESHOOTING CTS NURSERY PROBLEMS

21.1 Introduction

No enterprise is devoid of problems. The timing of their occurrence cannot be accurately predicted, but with proper management the frequency of their occurrence and the damage they do can be minimized.

Crises are action-demanding situations which are both important and urgent. Some require corrective action within minutes; others may require a response on a time scale of hours to several days. The nurseryman must size up each situation and react accordingly. Over-reacting can be just as harmful as not acting quickly enough, not only for the welfare of the crop, but for the smooth running of the whole nursery.

21.2 Be Prepared

Although no one can prepare for all possible contingencies, there are certain things that can be done ahead of time to prevent most emergencies from becoming disasters. Any production facility has certain standard operating procedures which, after the initial shakedown, represent the best procedures known. Changes in procedure, control settings, or timing should be made with caution. A record of the change should be kept, and everyone who needs to know should be informed of it.

A stock of spare parts should be kept of those items whose function is critical, that need regular replacement, are hard to find, or take a long time to get (section 6). Those items that may be needed in an emergency should be labeled to indicate where they go or what they fit.

Since no one is available all of the time, more than one person should know what to do in an emergency (section 19.2). Everyone who may be called upon should know:

1. What conditions are normal. This is necessary to recognize an abnormal situation which requires correction.
2. What conditions require immediate attention, and what can wait. No one likes to be hauled out of bed in the middle of the night to fix something that could have waited until morning, but it is at least as bad to be complacent about something that should be fixed immediately.
3. How to fix what is wrong. Everyone involved should be familiar with the troubleshooting procedure.
4. Where the tools and spare parts are. Tools and spare parts should always be kept in the same place, always be in their place, and be where someone can get to them quickly. When there is a crisis, nothing is more exasperating and time wasting than having to hunt for tools and parts.
5. Who to call if help is needed.

21.3 Be Alert to Problem Development

The sooner an abnormal condition is recognized, the more time there is to correct it before any damage is done. The key is to know what constitutes the normal condition and be alert enough to recognize when something is out of place.

There should be a checklist posted in the greenhouse indicating what the control settings are, the condition of the crop, and other information necessary to recognize a normal situation.

21.31 How to Use All of Your Senses All of the Time

When approaching the greenhouse, make a conscious effort to observe if things are normal. On a warm sunny afternoon, fans should be running. On a cold day, the furnaces should be on and the vapors from the flue pipe visible. If they are not, investigate. Is the double layer of plastic inflated and firm, or flapping loose? If it is loose, check the inflation blower. If the blower is running properly, check for holes in the skin. If you are visiting the greenhouse at night, notice if the lights for photoperiod control come on when they should. If it is during the hardening phase, has someone left a light on where it shouldn't be?

Listen as you approach the greenhouse. Does any running motor squeak like it needs oiling? Do you hear the hum of a running motor, but nothing is turning? Look for a broken belt or a stalled and overheating motor. Do you hear water running? Should it be running? Is the furnace running smoothly, or is combustion uneven?

Use your nose. Is the furnace properly tuned, or is combustion not complete? Did the pilot light go out? Has the house just been fumigated? If so, are the warning signs posted on the doors?

Enter the greenhouse. In fact, make it a point to visit the greenhouse on your way from one place to another, just to walk through. This will increase the supervision of the greenhouse without the need to make extra trips. As soon as you enter, your sense of touch will tell you if temperature and humidity are within an acceptable range. Your nose should indicate whether heaters and CO_2 generators are operating properly and if insecticides or certain fungicides have recently been applied. Your ears can tell you a great deal about proper operation of electric motors and fans, and indicate problems needing attention. Look around and observe carefully. Are the fans and furnaces doing what they should, considering the ambient temperature and humidity? Is the CO_2 generator on? Are pilot lights lit? Check the hygrothermograph (section 21.32). Are the lights coming on when they should? Are any burnt out?

Examine the seedlings closely. Is the morphology of the shoot correct and normal for their current stage of growth? Any signs of nutrient deficiencies or toxicities? Is the rootball moisture at or close to field capacity? Are the roots healthy, or is there evidence of root rot? (Mycorrhizae will appear on healthy roots. Do not mistake them for rot organisms). Is the foliage healthy, or are there signs of mold or mildew? Are insects present? (On hardwoods look on the underside of the leaf). If so, what are they? If they can damage the trees, apply control measures. If they are harmless, do nothing.

Each greenhouse is a little different, and it is hard to be specific about how to check out greenhouses and greenhouse crops quickly. The nurseryman should make a checklist to use as a training aid to teach his staff how to be alert and what to look for.

21.32 How to Read Hygrothermograph Charts

A hygrothermograph gives a record of temperature and humidity independent of all the other machinery (section 6.56). It can indicate normal operation, various intermittent and continuing failures, and give important clues as to what went wrong and how to correct it. Below are examples of hygrothermograph patterns and how to interpret them. Figure 21-1 represents "normal" tracings. The following items describe the features numbered on the chart:

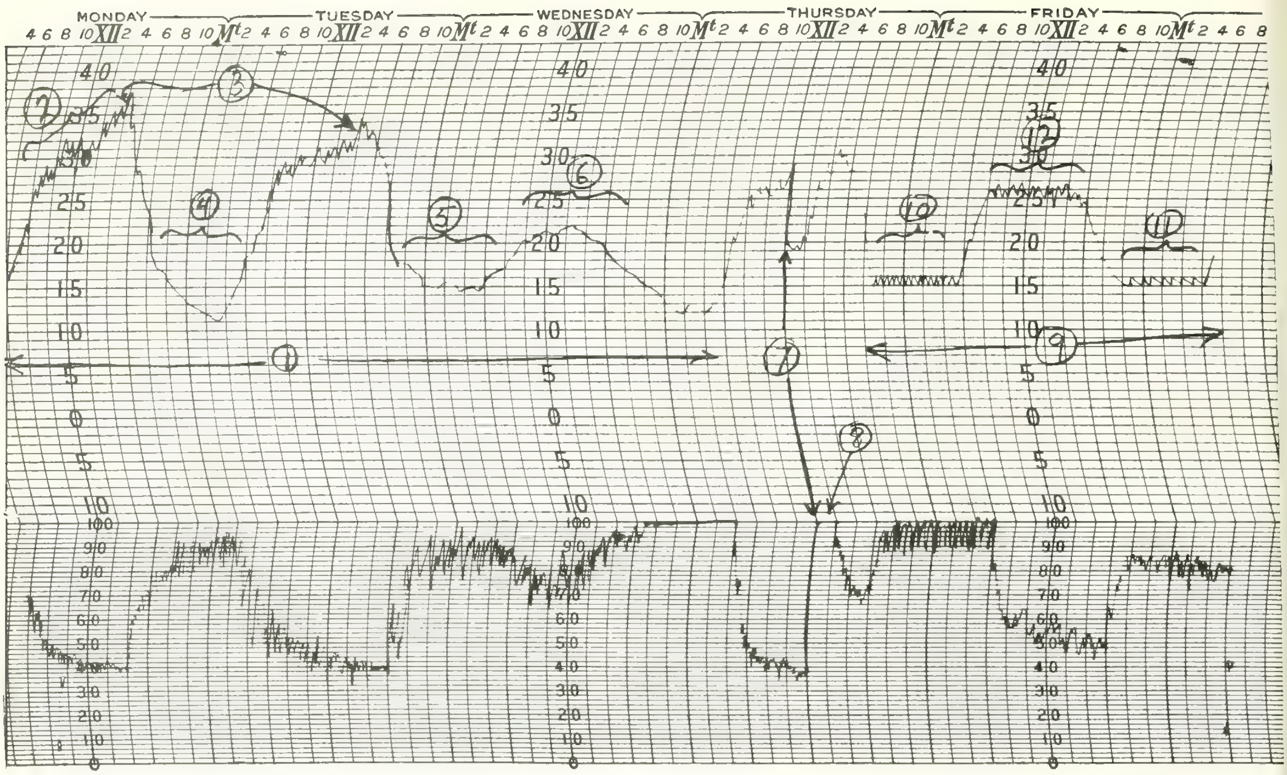

Figure 21-1—Normal hygrothermograph patterns.

1. This represents 3 days in a situation where neither heat nor cooling is applied.
2. The irregular and frequently rising pattern is typical of a sunny day. The rapid and random fluctuations are caused by clouds and the rapid fluctuation of sunlight intensity.
3. Certain fluctuations are caused by shadows from fixed objects. These occur at almost the same time each day, gradually changing with sun angle and season. As long as the hygrothermograph is kept in the same position and orientation, preferably with the sensor end facing north, these shadow patterns become recognizable markers which can be used to check on the timing of the hygrothermograph and are known to be normal, i.e., do not indicate a malfunction of any kind.
4. During a clear night, the temperature usually falls steadily until dawn. An interruption in this pattern usually signals a weather change.
5. Cloudy nights generally do not get as cold and reach minimum temperature sooner. They remain near minimum most of the night.
6. Overcast days do not get nearly as warm as sunny days, and the chart does not exhibit shadow patterns.
7. When the crop is watered during the day, there is a sudden drop in temperature and a sudden rise in humidity to 100%. This is a very useful marker which shows when each watering occurs. To show this the hygrothermograph must not be removed during watering.
8. The pen draws a straight line at 100% humidity. If the instrument is watered along with the seedlings, it will read 100% as long as there is any liquid water on the sensing element. This is also a good indication of the length of time the foliage stays wet during and after watering. In this example, that is about 2 hours. The straight horizontal trace indicating 100% humidity is quite characteristic and can be used to check the calibration of the hygrothermograph. If the trace is not reading 100%, adjust the instrument until it does.
9. A greenhouse in which the temperature is controlled by heating and cooling is characterized at night by temperatures oscillating in a 1°C range at the furnace thermostat setting. On a sunny day, the temperature rises above the furnace setting until the cooling comes on.
10. A rapidly fluctuating level night trace indicates that the furnace is cycling on and off at short intervals. On cold nights, that is normal. If the night is not that cold, look for major heat leaks.

11. An open sawtooth pattern indicates that the furnace comes on at infrequent intervals, typical of a mild night.
12. The daytime pattern is rarely as uniform as nighttime, because shadow patterns are superimposed on the cooling cycle pattern. Nevertheless, if the cooling system is adequate and working properly the trace should be more or less level at the set cooling temperature.

Figure 21-2 shows patterns to watch for which indicate equipment inadequacy or malfunction. The following numbered items describe the features numbered on the chart:

1. There are three malfunctions of the hygrothermograph itself that are easily recognized. When it draws a vertical trace on both the temperature and humidity scales and the pen is no longer at the correct time, the clock has stopped. Wind the clock and set the drum for the correct time. If it is not ticking, or if it will not keep time, the clock mechanism needs repair.
2. When one trace fades away, but the other remains normal, the pen is out of ink or is not in contact with the paper. Refill the pen or adjust the arm so that it makes positive contact with the chart.
3. When the humidity trace draws a stright line at its upper limit and that line is not on the 100% mark, change the humidity calibration adjustment until it reads 100%.
4. A daytime pattern in which the temperature is not held at the setpoint during the hottest part of the day, but is held satisfactorily in the morning and late afternoon indicates inadequate cooling capacity. Check all fans, the evaporation pads, water pump, and louvres for proper operation. Part of the system may not be working. If everything is working properly, then perhaps this is one of those few days of the year when the heat load exceeds the design capacity of the cooling system. If it happens frequently, the cooling system is not adequately designed, or the climate is too humid for evaporative cooling to be efficient.
5. When the temperature falls well below the setpoint before the furnace comes on, suspect a sticking thermostat. This usually occurs at the very beginning of the heating period and tends to be self-correcting, but if it occurs repeatedly, replace the thermostat.
6. In a well designed system with two stages of heating, failure of the first stage automatically turns on the second stage after a drop of only a few degrees. No damage is done, but the first stage should be examined promptly and made operational again.
7. On a sunny day, sudden failure of the entire cooling system causes an abrupt rise in greenhouse temperature. The most frequent cause is a power failure. On hot sunny days, these peak temperatures can be highly damaging and call for immediate action. Excessive temperature should trigger an alarm which will summon help. The temperature will come back down when the power comes back on,

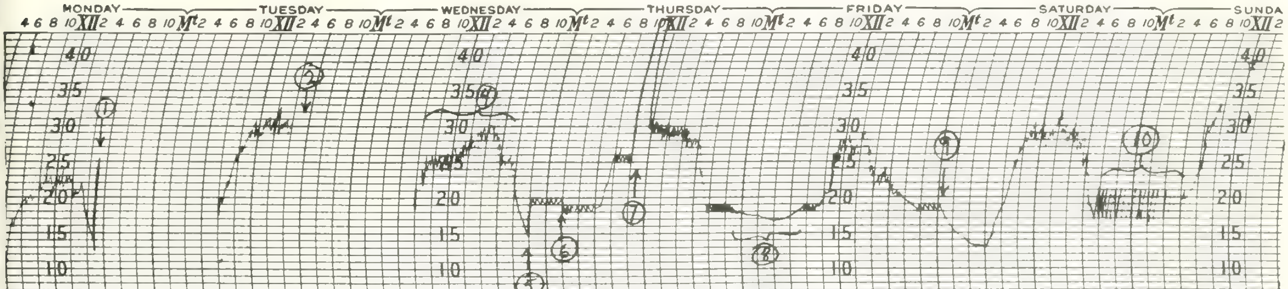

Figure 21-2—Hygrothermograph patterns which indicate malfunctions.

and unless someone was there, no one would know that the outage occurred except for the hygrothermograph record. The damage will show days or weeks later.

8. If the temperature gets so cold that the furnaces remain on continuously and still can't maintain the set temperature, the trace will be a line which parallels the outside temperature plus the differential that the heating and insulating system can maintain. This may occur a few times a year on the coldest nights. If it occurs regularly, the heating system is underdesigned.
9. When the entire heating system fails, the temperature drops in an uncontrolled fashion. This is most frequently caused by power outage or lack of fuel. If the heating system depends on a single furnace, look for a variety of things that can go wrong.
10. A wide fluctuation between high and low temperature during furnace operation can mean a variety of things, none of which are serious. This pattern will appear if the hygrothermograph is in direct line with the hot air blast from the heater. If so, try another location for the instrument. The temperature will commonly fluctuate more in an empty greenhouse than in one full of trees. In that case don't worry about it. The air from the furnaces may be too hot or not getting distributed evenly. Adjust furnace temperature or air flow system accordingly. Finally, the thermostat may have too great a differential, either because it is not set right or because it is wearing out. Readjust or replace it as needed.

21.4 Temperature Crises

When the temperature becomes either too hot or too cold because of failure of the temperature controlling machinery, a crisis frequently occurs which requires immediate action. Since emergency measures are sometimes damaging in themselves, the nurseryman must decide in each instance how fast to react and what actions represent the least of the evils.

21.41 Lack of Heat

When it is very cold outside and the furnace fails, temperatures in a double wall polyethylene greenhouse can fall at the rate of 0.5° C per minute. This allows only 20 minutes between 10° C, a typical alarm temperature setting, and freezing. If the plant material is succulent, immediate action is required. Even if the seedlings survive freezing, they may be thrown into irreversible dormancy. In the early stages of hardening, freezing may damage seedlings, but growth stoppage usually is not important. If the freeze occurs late in the hardening process, usually no harm is done.

First, locate the cause of lack of heat. If it will take long to correct, prepare to apply emergency heat. Look for the simple things first.

Power failure.—If all of the power is off, start the emergency generator and shut off everything that is not essential in order not to overload the generator.

Furnace off.—Check the fuel supply first. If it is adequate, check the furnace, the pilot light may be out. Relight it. If it will not stay lit, replace the burned out temperature sensor. If the fan is not running, check the circuit breaker and press the reset button. If the fan does not start, smell the motor and turn the fan blades by hand. If the motor smells burnt or the fan will not turn, try oiling the bearings and turning the blades. If it still won't start, replace the motor. If the motor runs but there is little or no air flow, tighten or replace belts. If it is an oil furnace that is off, push the reset button. If it fails to start, check the circuit breaker and motors as above. If it starts but won't stay lit, clean or replace the electric eye or faulty stack switch.

Cooling fan on.—Check for stuck thermostat or wrong setting. Shut fan off at circuit breaker if necessary.

Vents stuck open.—Close them manually. Free and oil them. Check for stuck thermostat or wrong setting.

Loss of skin or roof.—Cover seedlings with plastic. Apply heat underneath.

21.42 Emergency Heat Sources

If greenhouse temperatures can be kept above −8° C, the most generally useful and readily available emergency heating is the irrigation system. Turn it on and let it run continuously, until the heat is back on and greenhouse temperatures are well above freezing. The pipes will not freeze as long as the water is flowing in them, and the freezing of the water on the foliage of the seedlings will release enough heat to protect them from freezing. Irrigation is also effective if the cover or roof is lost, but is of limited usefulness in a strong wind, and should not be attempted if the temperature is expected to go below −8° C. (First the nozzles and then the pipes will freeze.)

Lights for photoperiod control can be turned on continuously to the limit of the capacity of the electrical circuit (section 6.2). The heat output is limited, but since it is radiant energy heating the foliage, it is being applied very efficiently.

The CO_2 generator is also a small heater, and in an emergency can be of significant value (section 6.3).

Portable heaters can be moved into the greenhouse. Oil burning types produce fumes toxic to both humans and plants. Their use should be limited to situations where there is no alternative to save the crop.

21.43 Excessive Heat

An overheated greenhouse demands prompt action (section 6.1). The usual cause is a cooling system failure, and temperatures on a hot sunny day can rise at the rate of 1° C per minute. If a power outage has occurred, switch to the emergency generator, and shut off everything that is not essential. If that is not the problem, check thermostats to be sure they are set correctly and working. Reset or replace as needed. Failure of only part of the cooling system usually does not result in a crisis, but should still be corrected promptly.

There are generally two alternative cooling methods: 1) manually open all of the doors and louvres; 2) turn on the irrigation. In a small greenhouse the first can be quite effective, but is of limited value in a large one. The second method is quite effective in holding the temperature within bounds, can be done quickly, and often is independent of public electric power.

21.44 Fire

Although greenhouses are generally low hazard areas, fires do occur. The immediate response should be to turn on the irrigation and turn off all nonessential electricity in the vicinity of the fire, especially the cooling system. The cooling fans will, otherwise, come on in response to the rise in temperature and quickly spread the fire throughout the house (Hartman 1978).

In a glass and metal frame greenhouse, the structure is fire safe, but most types of container are made of polystyrene or polyethylene, both of which will burn vigorously once ignited. The risk in the greenhouse, especially after the containers are filled with mix and wetted, is quite minimal, but fire hazard should be kept in mind where the empty containers are stored.

If a wooden framed plastic film covered greenhouse burns, heat builds up near the roof, the plastic melts, opens a hole, and releases the heat, so the fire does not spread rapidly. In contrast, a fiberglass greenhouse is strong enough to hold the heat until the whole structure is on fire. Once fiberglass reaches its decomposition temperature, the fire spreads very rapidly, and most of the fire is above what would be wetted by the irrigation system. Irrigating may still save the crop.

21.5 Water Crises

Too much or too little water is never a good thing, but there is usually more time available to solve the problem than there is with temperature crises.

21.51 Flood

Properly sited facilities should not be subject to flooding from the outside. However, if a flood can be anticipated, the facility can be diked and then bailed. If there is not time, about all that can be done is to wait for it to subside and then clean up. If there is any time at all, shut off all electrical equipment that will be flooded, and if possible, move anything that can be damaged to someplace above the flood.

Flooding from the inside is usually caused by a broken water line. Immediately shut off the water main, and then repair the break.

Localized excesses of water are usually caused by uneven distribution of the watering system or drips from nozzles and other structures (section 21.64).

21.52 Lack of Water

Depending on temperature and humidity, lack of water can continue without damaging the seedlings for a matter of hours up to several days, except when water is needed immediately for emergency heating or cooling during a temperature crisis. If the nurseryman is watching his crop at all, any lack of water will be due to equipment malfunction and not lack of attention. When waterlines break or pumps quit working, there is usually no water at all, and the problem and its solution immediately become apparent. Sometimes an automatic watering device in the greenhouse will break down. Then there is water available in the greenhouse, but no way to apply it automatically. The greenhouse should be equipped with valves where hoses can be attached, so that in an emergency, the house can be watered by hand.

A lack of water which is harder to find is moisture stress caused by uneven distribution of water. This can be caused by a poorly designed irrigation system, but even the best systems must be watched for plugged nozzles, stuck impact sprinklers, valves that are not set right, or wrong pressure on the lines (section 6.4).

21.6 Cultural Problems

The previous sections of this chapter have dealt with machinery and environmental controls. When something goes wrong with these, a crisis often develops which demands action within minutes. Sometimes, the time frame for action is measured in hours, but never more than a few days. In contrast, cultural problems develop more slowly, require closer observation to detect at an early stage, and rarely are so urgent that the remedy cannot wait a day. However, cultural problems are just as important, and it is usually harder to find the cause and correct it than it is for mechanical problems. If the nurseryman recognizes he has a problem but can't identify the cause, he should seek professional help.

This section deals with diagnosis and prescription for maladies that have developed. However, in most cases if adequate care and preventive measures have been taken, these situations should not develop.

21.61 Delayed or Erratic Germination

If the seed has been tested and found viable, given the appropriate treatment required for germination, and if good sanitation procedures are followed, germination should be prompt and normal (section 17). The nurseryman should know what is normal for rate and total germination of the species and seed lot he is growing. This is the only way to recognize late or slow germination. If it occurs, take action immediately. This is especially true if there is partial germination and resowing is necessary. If there is much difference in age between the two batches of seedlings, dominance will be expressed, and some of the late comers will be suppressed, unless the first batch can be consolidated and the second kept separate.

First, dig up and examine the seed. If the seed is not there, the containers may have missed being seeded, or rodents may have taken it. Set bait or mouse traps and reseed.

If the seed is there but not viable, possibly bad seed was sown. If inadequate testing is suspected, reseed with good seed. If it appears to be preemergence damping off, apply fungicide (section 20.24) and reseed. If it is possible that the disease organism is borne on the seedcoat, surface sterilize the seed with 30% hydrogen peroxide or 1% sodium hypochlorite. (Be sure to check out the procedure before treating a large batch of seed. Soaking time can be critical, and the seed may heat up in the hydrogen peroxide.) If serious damping off occurs on the second try, resterilize the mix and containers.

If the seed is viable, but hasn't germinated, check recommended germination temperature against current greenhouse temperatures. Change greenhouse temperature if needed. Check depth of seed covering. If too deep, scrape some of the growing medium away. If too shallow, increase irrigation frequency.

Possibly there was inadequate pretreatment of seed. Resow with properly pretreated seed.

21.62 Insects

The greenhouse should be inspected regularly for the presence of insects (section 20). Do not wait for damage symptoms to appear. The frequency of inspection and the urgency of action depends on the stage of growth and the nature of the probable pest. For instance, sucking or chewing insects are serious pests during the juvenile and exponential growth phases. They are of little importance during hardening of hardwoods when the leaves are about to abscise anyway.

Examine the foliage thoroughly, especially the underside of the leaves. Look carefully; some insects are so small and so well camouflaged that they can easily be missed. When insects are found, identify them. Some are beneficial, some are harmless, and some require control. If harmful insects are found, apply recommended control measures (section 20.33).

21.63 Growth Problem Distribution

A great deal can be deduced by examining the spacial pattern in which the growth problem occurs. This section discusses the most common patterns and their probable cause, but the reader should also keep spacial pattern in mind when reading the following sections as well (sections 21.64-21.68).

Bread loaf effect.—Height growth will sometimes be greater in the middle than it is at the edges of a bench or sometimes a whole greenhouse, giving that block of seedlings the shape of a loaf of bread. The most common cause is inadequate air circulation, which causes localized differences in temperature and humidity. The cure is to have positive air circulation, especially during daylight hours and preferably under the bench (section 6). Another cause is that the containers at the edge of the bench are exposed to more light. This accelerates drying and may cause above optimum rootball temperatures. The problem can be minimized by using white or light colored containers. Styrofoam is especially good in this respect because of its insulating as well as light reflecting qualities. Watering should be programed to maintain adequate moisture in those edge containers subject to the most rapid drying. This means that the pot mix must be porous enough so the interior containers can tolerate the excess of moisture they will receive. Maintenance of adequate humidity will reduce the difference in water consumption between edge and interior cavities (section 11).

Rings or streaks.—Chlorosis or stunted seedlings grouped in rings, circles, or streaks usually indicates a non-uniform watering pattern (section 6.4). The watering pattern should be tested with an array of paper cups to determine whether the poor seedlings are getting more or less than the rest of the house. Usually, they are getting too much, and the problem is often compounded by a pot mix that is too fine to tolerate overwatering (section 9.3). The cure is to revamp the watering system to produce a more uniform distribution. On the next crop, use a coarser, more porous medium. If the poor seedlings are getting less than the more vigorous ones, increase the duration of watering and check to be sure that some solution leaches from the bottom of the least watered containers. If the medium is too fine, however, this can reduce the growth of the once healthy seedlings. The nurseryman should be alert to this and steer an intermediate course, if possible. Another alternative would be to hand water the deficient cavities without watering the entire house. The ultimate cure, of course, is a more uniform watering system and a more porous pot mix. This is definitely the way to prevent the problem from developing in future crops, but in the middle of the growing cycle, changing pot mixes is out of the question and changing irrigation systems is difficult.

Another cause is variation in light intensity at night (section 12.3). If there is a portion of the greenhouse that does not receive enough light at night, premature budset may result. When it is a matter of distance from the light the effect will be gradual over quite a distance. Sometimes an object will create a shadow, and the division between actively growing and dormant seedlings will be quite sharp. The best way to diagnose this condition is to visit the greenhouse at night. A hand light meter will tell you whether you are below minimum recommended intensity or not. If the pattern of growth is caused by variation in light intensity, it will be apparent without any instrumentation.

Scattered problem spots.—Although the development of disease may be aided by certain combinations of temperature and humidity which will occur in a recognizable pattern in a non-uniform greenhouse, disease often occurs in spots without any apparent spacial relation. Suspect disease, especially if the problem areas are confined to one species in a house where several are growing. Examine the symptoms carefully and see section 20.24 for help in diagnosis and cure.

No pattern; problem widely distributed.—Disease and insect attacks can be generally distributed and widespread throughout the greenhouse, but with any vigilance at all, most will be detected and corrective action taken when the problem is still confined to scattered spots. One exception is if a serious error has been made in the preparation of the growing medium(Section 9.3). For instance, if too much dolomite has been incorporated into the growing medium, the pH will become too alkaline after the crop is well underway. In this case, increase the acidity of the nutrient solution, and use less dolomite next time. If the growing medium contains toxic materials, such as anerobically fermented sawdust or fresh cedar shingle tow, or easily biolizable carbon sources, such as fresh sawdust or rice hulls, or it has not been sterilized adequately, or it lacks a required mycorrhizal fungus, then the problem may become apparent quickly and throughout the whole crop at once.

If the growing medium contains materials that have not been properly composted, about all that can be done is to raise the nitrogen level to 400 ppm, apply light doses of protective fungicides, and hope. If the problem can be discovered early enough, it would be much better to dump the whole crop, resterilize the containers, refill with a proper mix, and start over.

Fungus diseases (section 20.34) can usually be suppressed with fungicides, but most fungicides will not cure the seedlings that have already been damaged. They will only prevent the fungus from spreading to healthy tissue. If a mycorrhizal fungus is needed (section 14.1), it can sometimes be successfully added after a growth problem is recognized, either as duff or spores which are applied to the surface and watered in.

Another possibility is mineral nutrient deficiency or toxicity. Examine the symptoms carefully. Compare them with the symptoms listed in section 13.51. Have the leachate from the bottom of the container analyzed to see how much of each mineral nutrient is present and compare that with the formulation listed in section 13.61. If any of the quantities found by analysis are very different from what was expected, adjust the formulation of the nutrient solution accordingly. Another more precise way to measure nutrient status is by foliar analysis. Compare the foliar nutrient content with what is known to be normal for the species, seed source, and age class of the seedlings being grown. However, these analyses may not be useful to the nurseryman unless they can be done quickly (in less than a week). Otherwise, the crop may be too badly damaged to recover.

A third possibility is air pollution. If the nursery is located in a large urban area or downwind from certain pollutant-emitting industries, sensitive tree species, such as white pine, may suffer. Elaborate air filters or washing systems can alleviate the problem, but they are expensive. Air pollution should have been considered when selecting a location for the nursery (section 4.1).

If the source of pollution is within the nursery itself, it can be eliminated. The most common source is SO_2 produced by burning sulfur-containing fuels for heat and CO_2 generation. The latter is most critical, because the flue gases are emitted directly into the greenhouse. Check with the fuel supplier to make sure the carbon to sulfur ratio is 10,000 to 1 or more (section 14.23). If it is not, change fuels or shut off the CO_2 burner until a low sulfur fuel can be found. If the heating system is burning a high sulfur fuel, make sure the flue gases are carried well away from the greenhouse and do not enter it. If this is not possible, switch to a low sulfur fuel. If an oil burning space heater must be used for emergency heat, use kerosene or number 1 diesel oil. Do not use number 2 diesel or number 2 fuel oil.

The other internal source of pollution is ozone. Electric motors that are dirty or badly worn will arc excessively and generate appreciable quantities of ozone. Clean or repair the motors if this condition is found.

21.64 Disease

Sometimes the mycelium or fruiting bodies of a fungus are visible on necrotic parts of the seedling. This is of great help in diagnosing the disease, but more often the diagnosis must be based on location, color, or shape of deformity. See sections 20.21 and 20.34 for assistance. Always identify the disease before treating it. Success is more likely than if a shotgun approach is tried.

21.65 Wilting

Wilting is caused by the inability of the roots to replace moisture as fast as the foliage is losing it. The most common cause is lack of moisture in the rootball. If this is the case, water immediately and modify the watering schedule to be sure that wilting does not occur repeatedly. Sometimes wilting will occur on hot days in otherwise healthy, well watered seedlings. Try increasing the humidity and decreasing peak day temperatures by watering in the hottest part of the day.

Wilting can also be caused by poor root aeration caused by a tight waterlogged mix. In this case, wilting is usually accompanied by chlorosis and stunted growth. Reduce the frequency of watering, and use a more porous mix for the next crop.

A waterlogged mix can lead to root rot. If this is found, apply fungicide periodically (section 20.34) and reduce the frequency of watering. Do not reduce the amount of water per irrigation, however, as this may lead to a buildup of salts. Use a more porous mix for the next crop.

If the mix is both well watered and well aerated, and root rot is not evidence, look for wilt disease inside the stem. If nothing can be found, look for nematodes in the pot mix. If found, treat as in section 20.34. On the next crop, do a better job of sanitation in the greenhouse and sterilization of the mix and containers.

21.66 Chlorosis

Chlorosis is a reduction in the amount of chlorophyll present and is a general symptom of many maladies, but careful observation of where on the leaf and seedling it occurs can yield important clues.

If only the newest growth is chlorotic and the foliage is of normal size, suspect iron deficiency (section 13.51). Increase the iron chelate in the nutrient solution, and make sure the pH of the nutrient solution is close to your target: 5.5 for most conifers and 6.5 for most hardwoods (section 13.32).

If needle tips are chlorotic with necrosis frequently occurring at the very tip or there is yellow interveinal mottling of hardwoods, suspect SO_2 injury, and proceed as in section 12.63. If the damage is general or concentrated on the older foliage and is accompanied by stunting, suspect nitrogen deficiency. Increase the amount of nitrogen in the nutrient solution and check the pH. Similar symptoms can be caused by waterlogged pot medium. If this is the case, reduce the frequency of watering, but do not reduce the amount of water per watering.

In the Pacific Northwest, root rot and chlorosis caused by waterlogged pot mix may occur in seedlings stored outdoors in the winter, especially when roots have effectively clogged the drainage holes. The cure in this case is to shelter them so that they do not receive large and uncontrolled amounts of rainfall.

Deficiencies of magnesium and sulfur will also cause chlorosis somewhat different in pattern from either iron or nitrogen deficiency (section 13.51). In general, if a nutrient deficiency is suspected, 1) check the pH and formulation of the nutrient solution, 2) get a foliar analysis of some damaged tissue and compare with the analysis of healthy tissue, and 3) try painting or spraying a salt solution of the suspected element on the damaged tissue. If the problem is corrected in 1 to 2 weeks, you have probably guessed right.

21.67 Brown or Necrotic Spots on Leaves or Stem

This is a commonly observed symptom which could be due to many causes. It is characteristic of ozone damage. Check electric motors in the greenhouse for excessive arcing. If due to photochemical smog, filter all incoming air through activated charcoal, or move the nursery.

Deficiencies of P, Ca, Mg, and toxic levels of B may produce necrotic spots in combination with chlorosis or other characteristic colors. See section 13.51 for details of nutrient deficiency symptoms.

Diseases can also produce similar symptoms. See section 20.21 or consult Peterson and Smith (1975).

21.68 Lack of Growth or Premature Dormancy

If the species being grown is one that has been well researched and requirements for optimum growth can be specified with reasonable certainty, then the first step is to check all of the environmental controls for proper setting and function. If anything is off, return it to the known optimum. Check the hygrothermograph charts and daily log for short term malfunctions or mistakes in procedure, such as too long a period without water, or failure to inoculate with a required mycorrhizal fungus.

If there is limited knowledge about the requirements of the crop, examine the herbarium specimens or measurement records from previous crops to determine what was different about the procedure or conditions that produced good crops before. If a specific lead can be found, it will make it much easier to either restimulate growth or to show that growth is not likely to resume.

If a specific probable cause can be found, correct whatever is non-optimum, but for many species that will not be enough to reverse the onset of dormancy. If better or more specific information is not available, try the following in sequence until one works.

1. Increase the intensity of light at night to 60 foot-candles (650 lux) and the duration to 1 part in 8 (section 12.3).
2. Increase the night temperature to 72°-75° F (22°-24° C).
3. Raise the nitrogen level in the nutrient solution. Most species can tolerate 400 ppm without adverse effects.
4. Spray with 50 ppm gibberellic acid.
5. Add a suitable mycorrhizal inoculum and water it in.
6. Accept a smaller tree.
7. Put the crop through dormancy and hardening. Flush again, then harden and ship.

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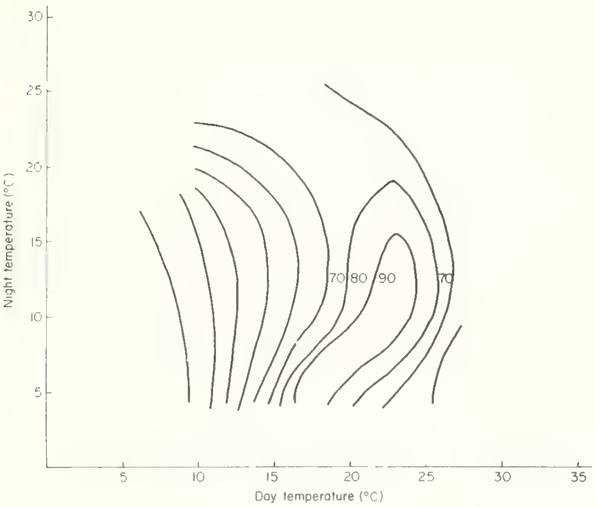
Appendix 1

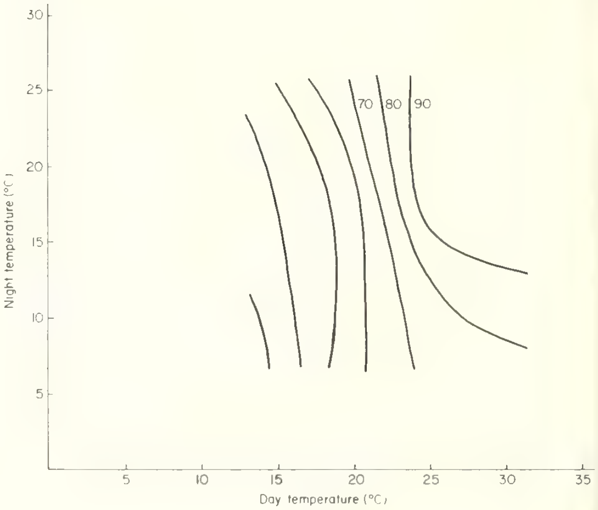
Growth in percent of maximum of various tree species and seed sources as a function of day and night temperature. See section 10 for interpretation and use of the graphs. Some information is also available about the following species:

Species	Authority
Western hemlock	Brix (1971) Owston and Kozlowski (1978)
Jeffrey pine	Hellmers (1963)
Loblolly pine	Hellmers (1962)
Northern red oak	Hellmers (1962)
Douglas-fir	Hellmers (1962)
Digger pine	Hellmers (1962)
Eastern hemlock	Olson et al. (1959)
Pitch pine	Good and Good (1976)

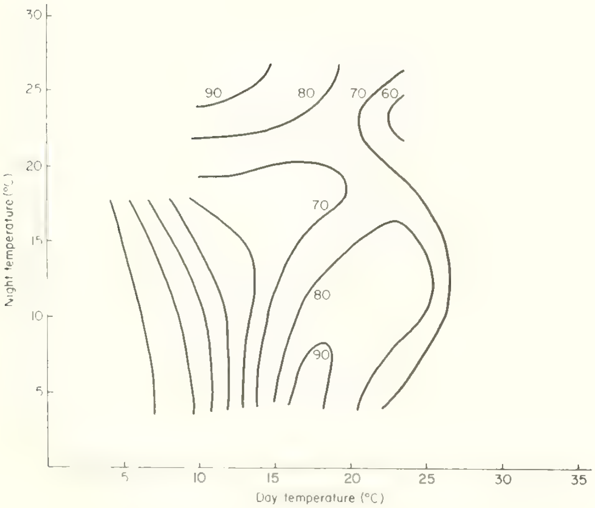
Species: *Abies magnifica*
Growth Parameter: Height
Maximum Size (= 100%): 108mm
Seed Source: Calif., No. Coast Pine Region, 6,000 feet (1,800m)
Coefficient of Variability: 8%
Authority: Hellmers (1966)



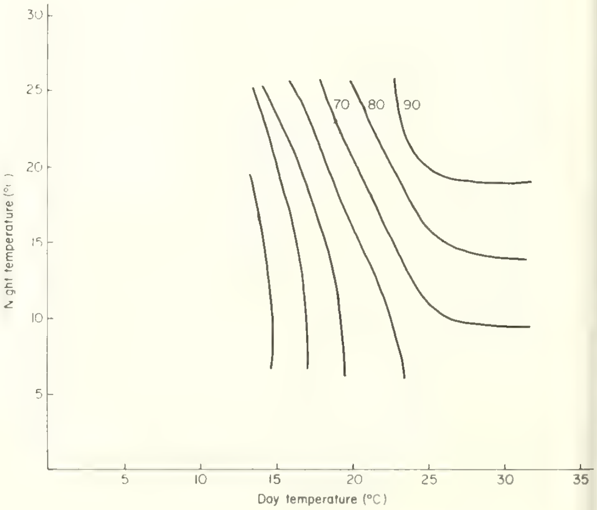
Species: *Celtis occidentalis*
Growth Parameter: Height
Maximum Size (= 100%): 615mm
Seed Source: South Dakota
Coefficient of Variability: 5.2%
Authority: Tinus (1974)



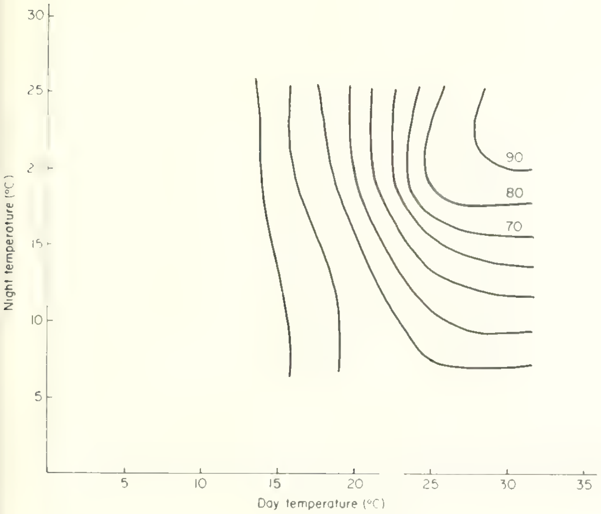
Species: *Abies magnifica*
Growth Parameter: Dry weight
Maximum Size (= 100%): 1.7gm
Seed Source: No. Coast Pine Region, 6,000 feet (1,800m)
Coefficient of Variability: 9%
Authority: Hellmers (1966)



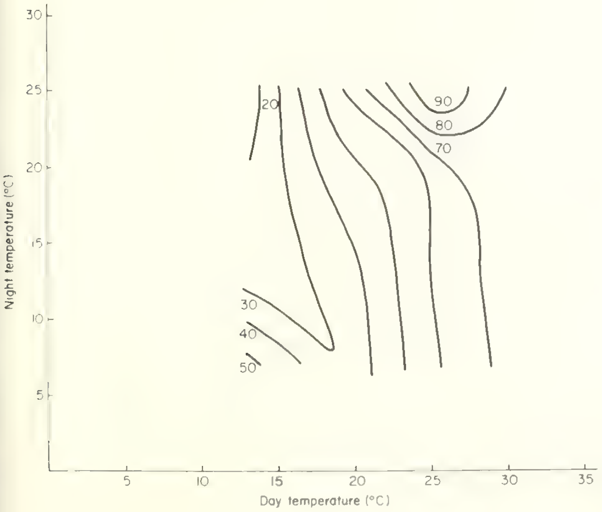
Species: *Celtis occidentalis*
Growth Parameter: Caliper
Maximum Size (= 100%): 5.2mm
Seed Source: South Dakota
Coefficient of Variability: 4.1%
Authority: Tinus (1974)



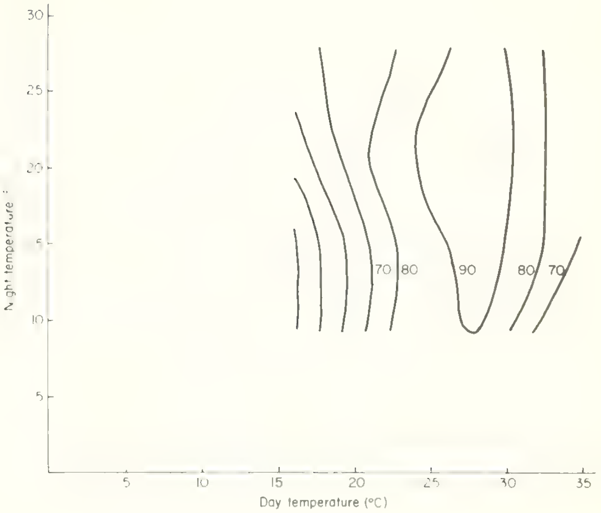
Species: *Celtis occidentalis*
Growth Parameter: Dry weight
Maximum Size (= 100%): 7.2gm
Seed Source: South Dakota
Coefficient of Variability: 13.5%
Authority: Tinus (1974)



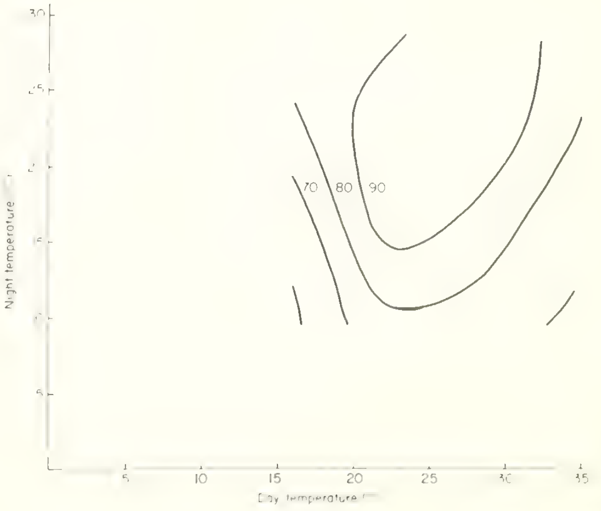
Species: *Celtis occidentalis*
Growth Parameter: Root/shoot ratio (dry weight)
Maximum Size (= 100%): 0.21
Seed Source: South Dakota
Coefficient of Variability: Not available
Authority: Tinus (1974)



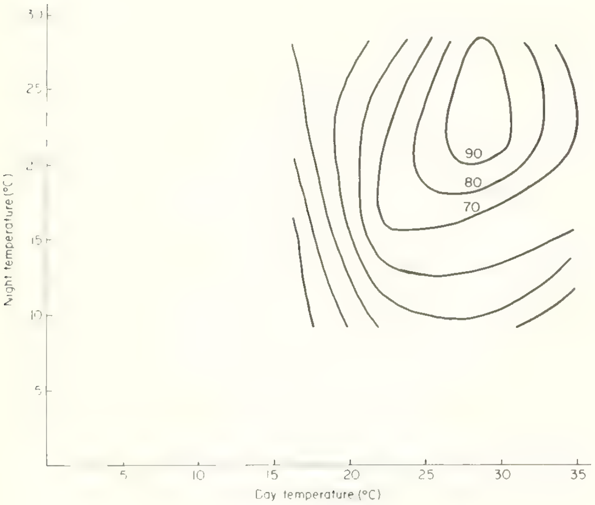
Species: *Juglans nigra*
Growth Parameter: Height
Maximum Size (= 100%): 680mm
Seed Source: Kansas
Coefficient of Variability: Not available
Authority: Tinus (unpublished)



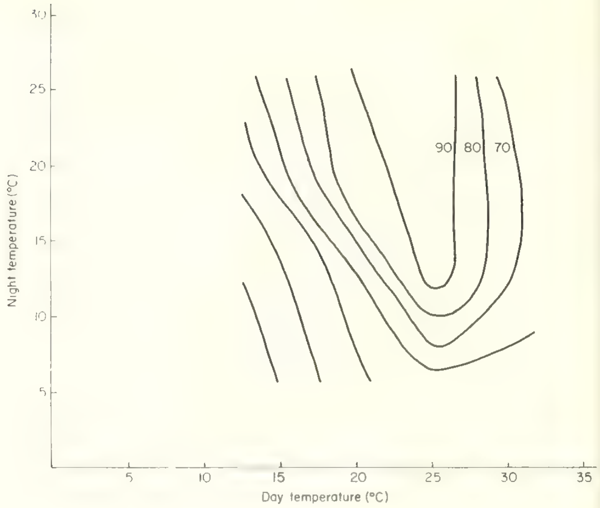
Species: *Juglans nigra*
Growth Parameter: Caliper
Maximum Size (= 100%): 7.35mm
Seed Source: Kansas
Coefficient of Variability: Not available
Authority: Tinus (unpublished)



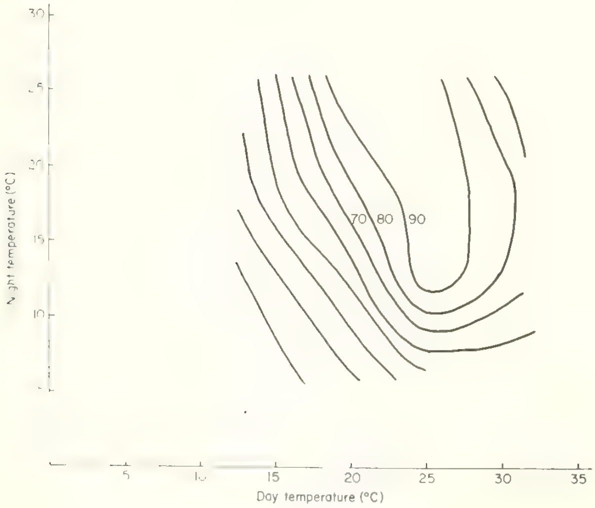
Species: *Juglans nigra*
Growth Parameter: Dry weight
Maximum Size (= 100%): 18.4gm
Seed Source: Kansas
Coefficient of Variability: Not available
Authority: Tinus (unpublished)



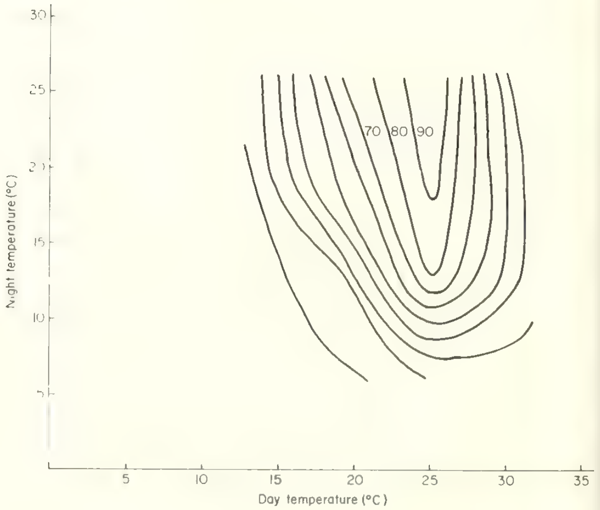
Species: *Juniperus scopulorum*
Growth Parameter: Caliper
Maximum Size (= 100%): 2.6mm
Seed Source: Towner, N. Dak.
Coefficient of Variability: 6%
Authority: Tinus (1972)



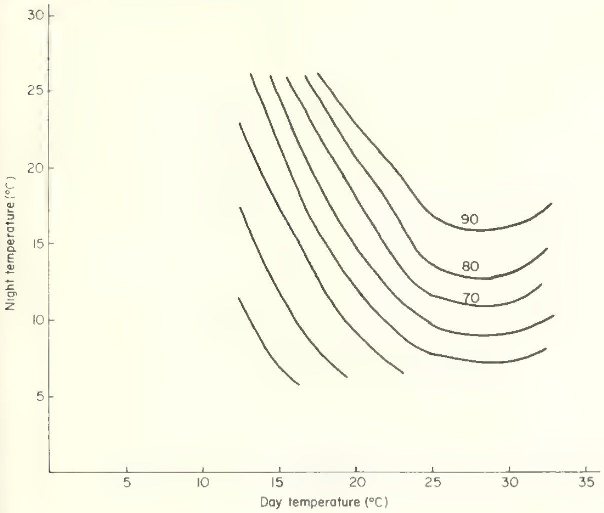
Species: *Juniperus scopulorum*
Growth Parameter: Height
Maximum Size (= 100%): 224mm
Seed Source: Towner, N. Dak.
Coefficient of Variability: 8%
Authority: Tinus (1972)



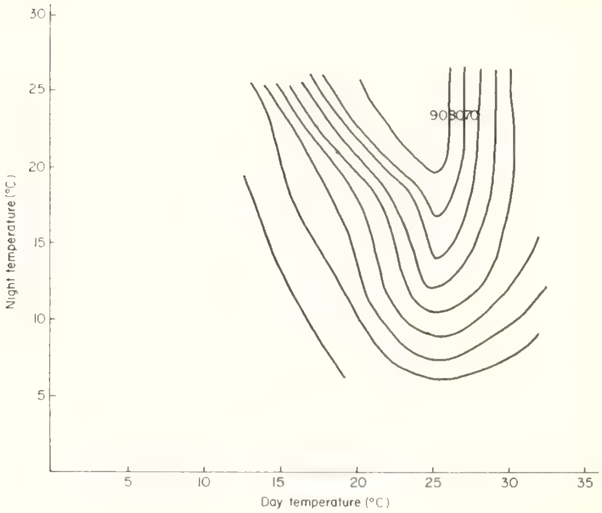
Species: *Juniperus scopulorum*
Growth Parameter: Dry weight
Maximum Size (= 100%): 5.6gm
Seed Source: Towner, N. Dak.
Coefficient of Variability: 18%
Authority: Tinus (1972)



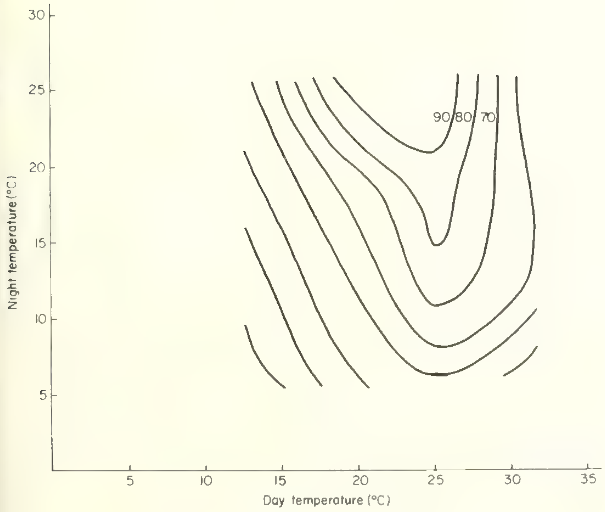
Species: *Juniperus virginiana*
Growth Parameter: Height
Maximum Size (= 100%): 279mm
Seed Source: Towner, N. Dak.
Coefficient of Variability: 6%
Authority: Tinus (1972)



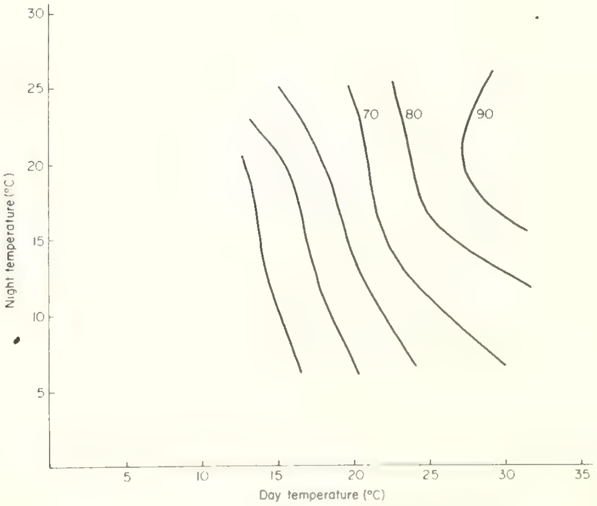
Species: *Juniperus virginiana*
Growth Parameter: Dry weight
Maximum Size (= 100%): 11.9gm
Seed Source: Towner, N. Dak.
Coefficient of Variability: 16%
Authority: Tinus (1972)



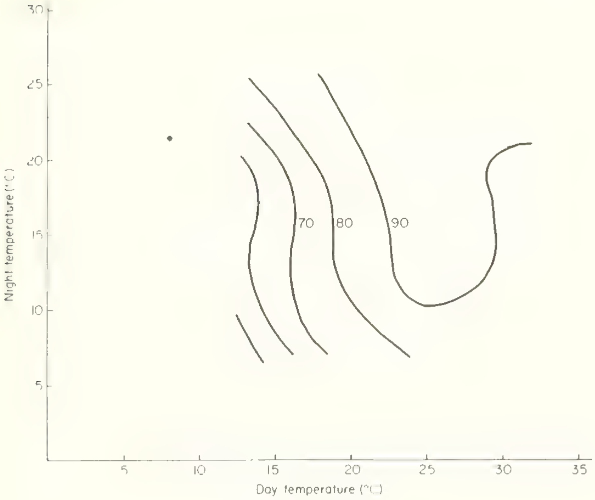
Species: *Juniperus virginiana*
Growth Parameter: Caliper
Maximum Size (= 100%): 6.2mm
Seed Source: Towner, N. Dak.
Coefficient of Variability: 5%
Authority: Tinus (1972)



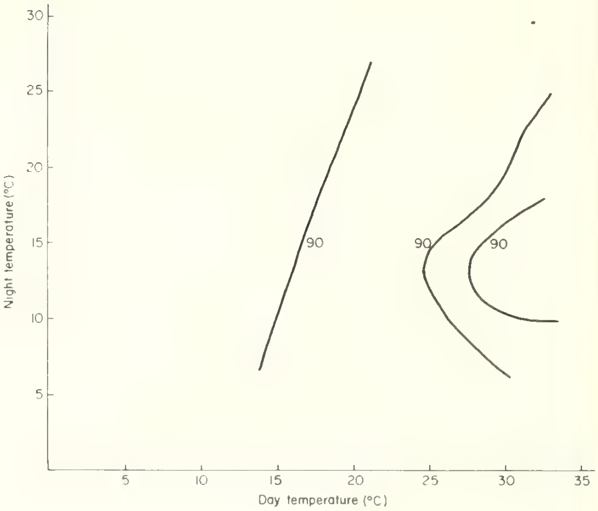
Species: *Larix sibirica*
Growth Parameter: Height
Maximum Size (= 100%): 314mm
Seed Source: Denbigh, N. Dak. (Russian origin)
Coefficient of Variability: 4.4%
Authority: Tinus (1973)



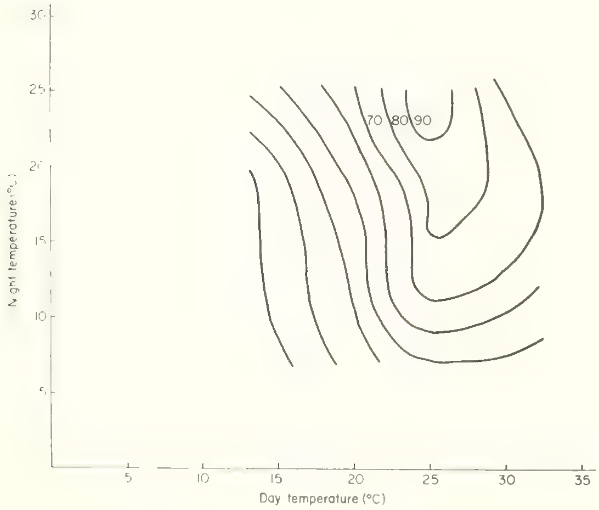
Species: *Larix sibirica*
Growth Parameter: Caliper
Maximum Size (= 100%): 6.3mm
Seed Source: Denbigh, N. Dak. (Russian origin)
Coefficient of Variability: 3.8%
Authority: Tinus (1973)



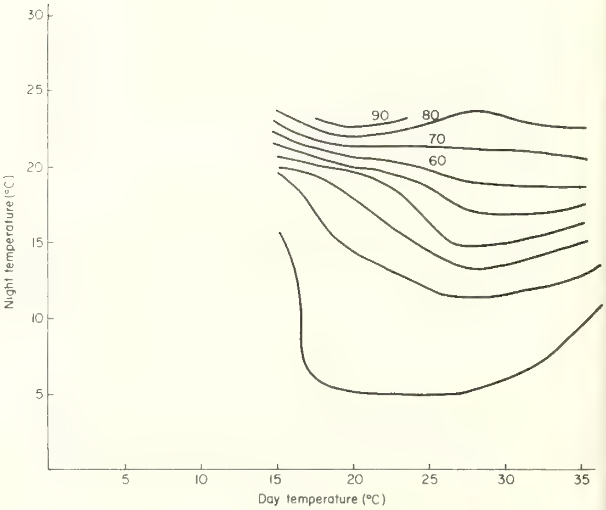
Species: *Larix sibirica*
Growth Parameter: Root/shoot ratio (dry weight)
Maximum Size (= 100%): 0.33
Seed Source: Denbigh, N. Dak. (Russian origin)
Coefficient of Variability: Not available
Authority: Tinus (1973)



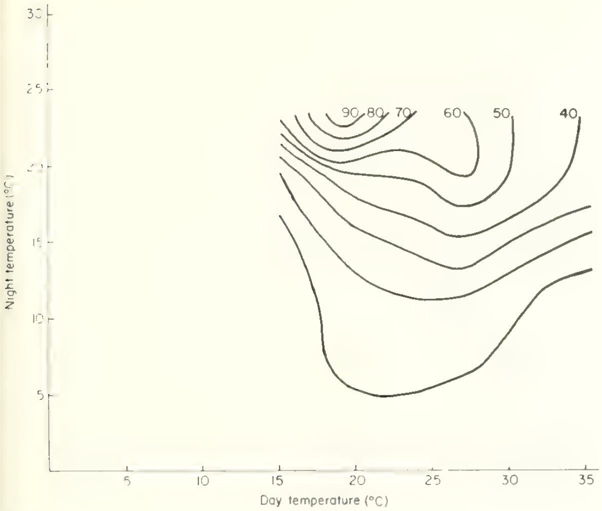
Species: *Larix sibirica*
Growth Parameter: Dry weight
Maximum Size (= 100%): 6.3gm
Seed Source: Denbigh, N. Dak. (Russian origin)
Coefficient of Variability: 10.9%
Authority: Tinus (1973)



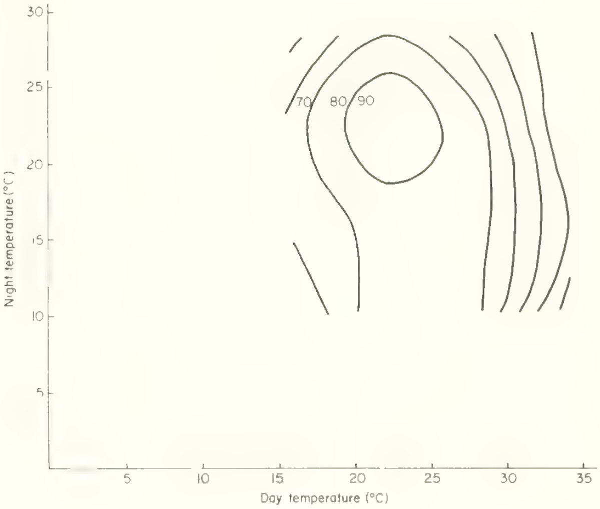
Species: *Picea engelmannii*
Growth Parameter: Height
Maximum Size (= 100%): 165mm
Seed Source: Larimer County Colo., 10,300 feet (3,140m)
Coefficient of Variability: Not available
Authority: Hellmers et al. (1970)



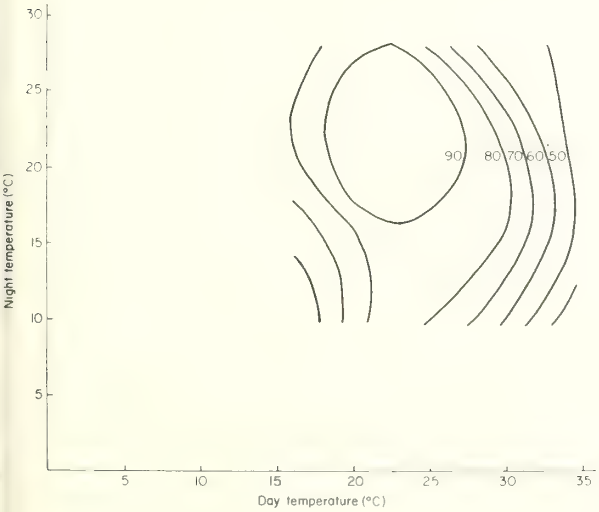
Species: *Picea engelmannii*
Growth Parameter: Dry weight
Maximum Size (= 100%): 8.3gm
Seed Source: Larimer County Colo., 10,300 feet (3,140m)
Coefficient of Variability: 17% ±
Authority: Hellmers et al. (1970)



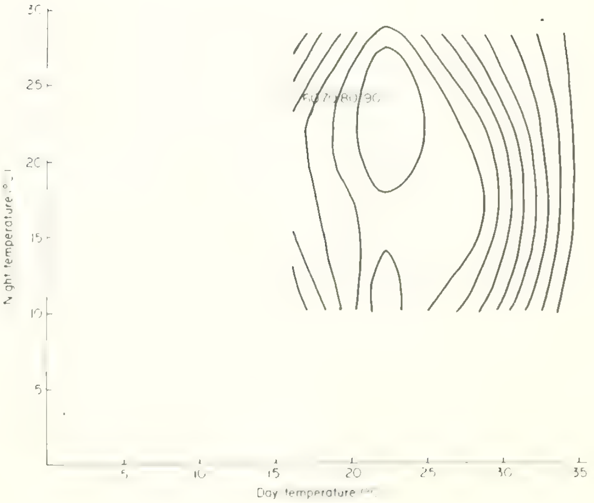
Species: *Picea glauca*
Growth Parameter: Caliper
Maximum Size (= 100%): 2.0mm
Seed Source: Kenai, Alaska, L-224
Coefficient of Variability: 6.8%
Authority: Tinus (1976)



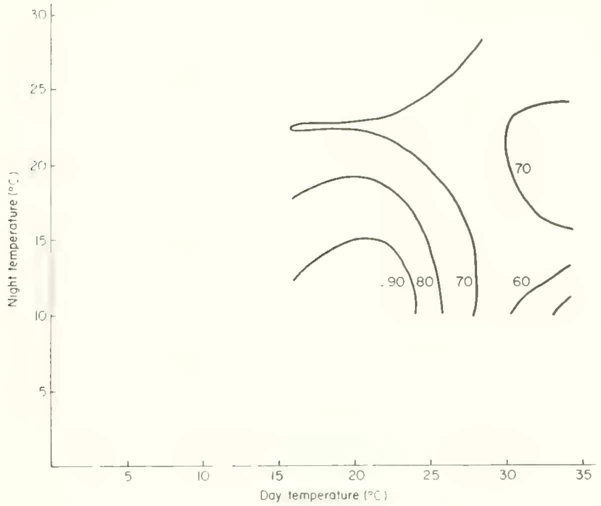
Species: *Picea glauca*
Growth Parameter: Height
Maximum Size (= 100%): 100mm
Seed Source: Kenai, Alaska, L-224
Coefficient of Variability: 9.9%
Authority: Tinus (1976)



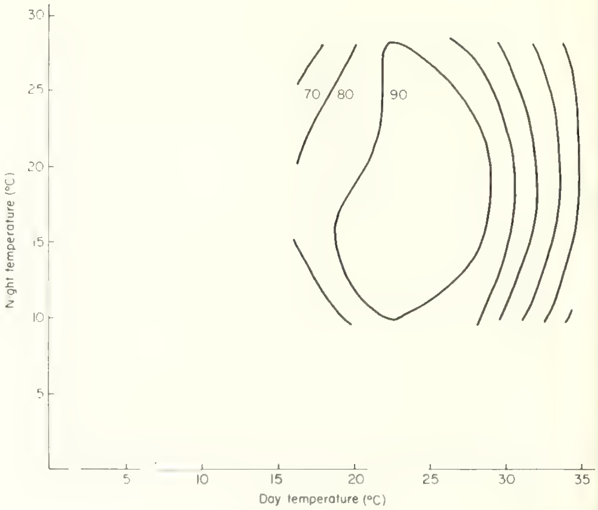
Species: *Picea glauca*
Growth Parameter: Dry weight
Maximum Size (= 100%): 0.43gm
Seed Source: Kenai, Alaska, L-224
Coefficient of Variability: 19.7%
Authority: Tinus (1976)



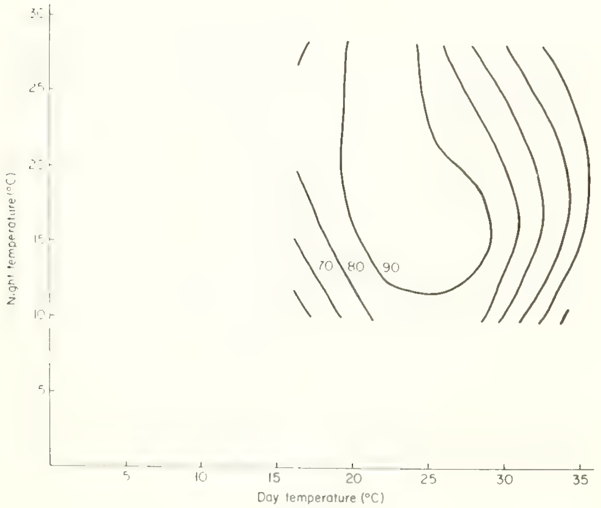
Species: *Picea glauca*
Growth Parameter: Root/shoot ratio (dry weight)
Maximum Size (= 100%): 0.33
Seed Source: Kenai, Alaska, L-224
Coefficient of Variability: Not available
Authority: Tinus (1976)



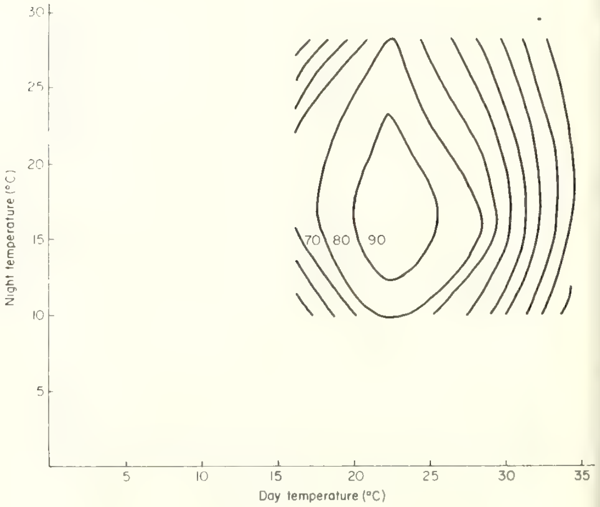
Species: *Picea glauca*
Growth Parameter: Caliper
Maximum Size (= 100%): 1.7mm
Seed Source: Fairbanks, Alaska, L-274
Coefficient of Variability: 3.6%
Authority: Tinus (1976)



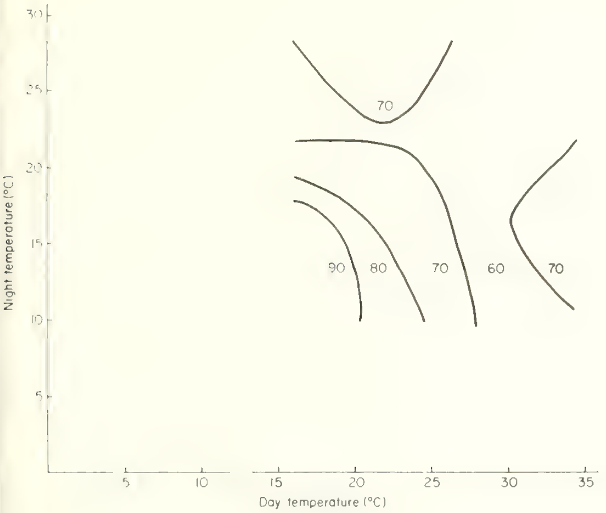
Species: *Picea glauca*
Growth Parameter: Height
Maximum Size (= 100%): 115mm
Seed Source: Fairbanks, Alaska, L-274
Coefficient of Variability: 3.5%
Authority: Tinus (1976)



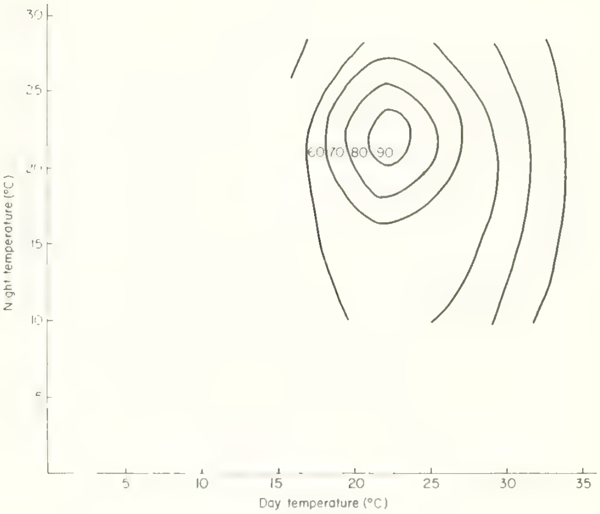
Species: *Picea glauca*
Growth Parameter: Dry weight
Maximum Size (= 100%): 0.39gm
Seed Source: Fairbanks, Alaska, L-274
Coefficient of Variability: 8.7%
Authority: Tinus (1976)



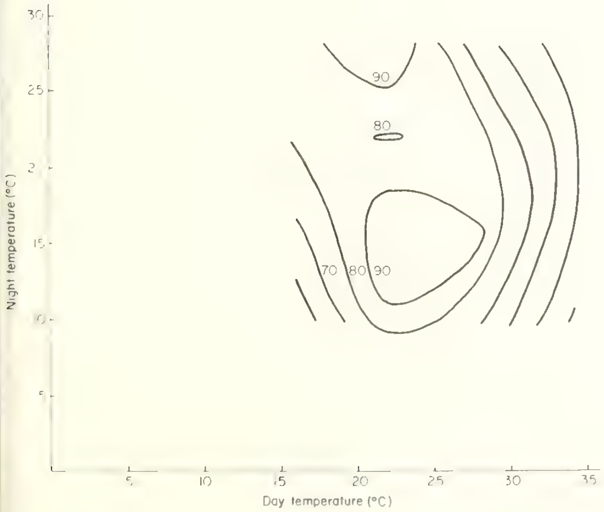
Species: *Picea glauca*
Growth Parameter: Root/shoot ratio (dry weight)
Maximum Size (= 100%): 0.35
Seed Source: Fairbanks, Alaska, L-274
Coefficient of Variability: Not available
Authority: Tinus (1976)



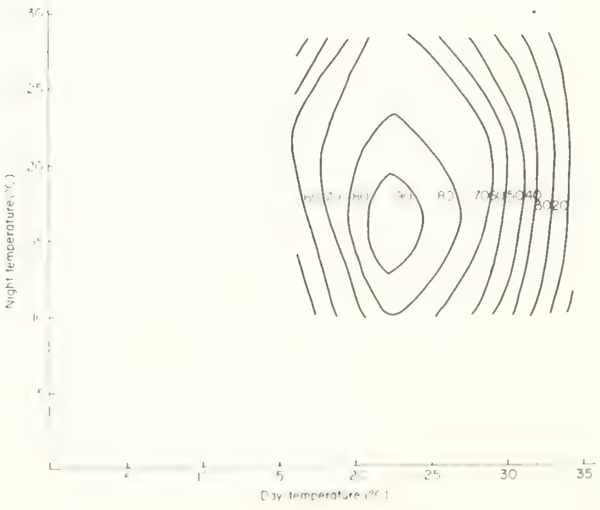
Species: *Picea glauca*
Growth Parameter: Caliper
Maximum Size (= 100%): 2.2mm
Seed Source: Central Alberta, DG-7986
Coefficient of Variability: 4.8%
Authority: Tinus (1976)



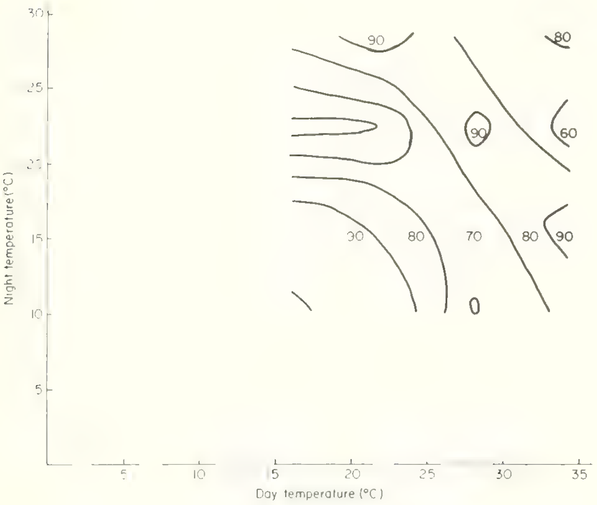
Species: *Picea glauca*
Growth Parameter: Height
Maximum Size (= 100%): 100mm
Seed Source: Central Alberta, DG-7986
Coefficient of Variability: 5.0%
Authority: Tinus (1976)



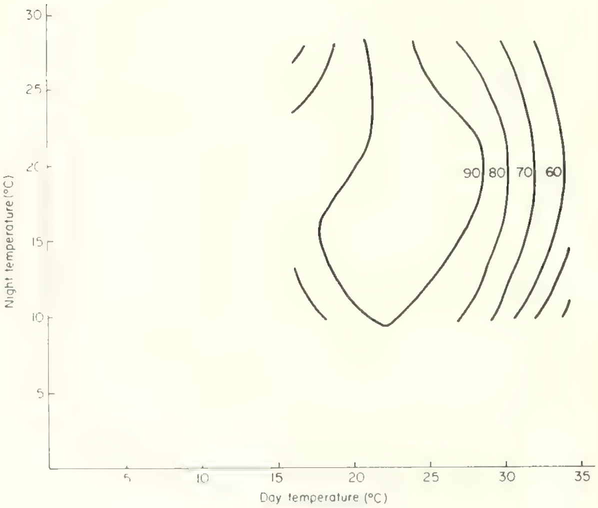
Species: *Picea glauca*
Growth Parameter: Dry weight
Maximum Size (= 100%): 0.36 gm
Seed Source: Central Alberta, DG-7936
Coefficient of Variability: 11.1%
Authority: Tinus (1976)



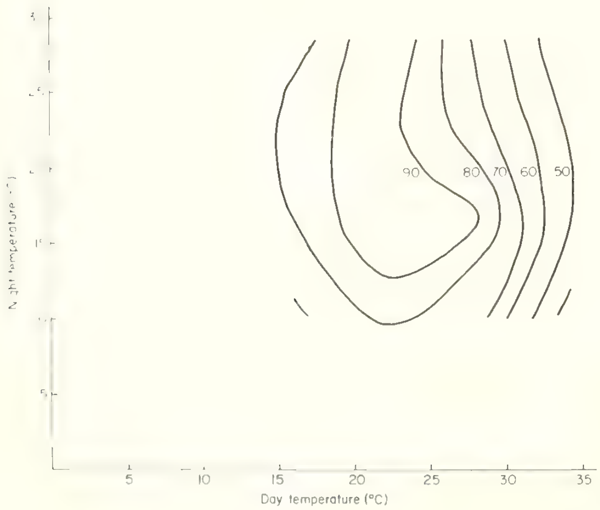
Species: *Picea glauca*
Growth Parameter: Root/shoot ratio (dry weight)
Maximum Size (= 100%): 0.21
Seed Source: Central Alberta, DG-7986
Coefficient of Variability: Not available
Authority: Tinus (1976)



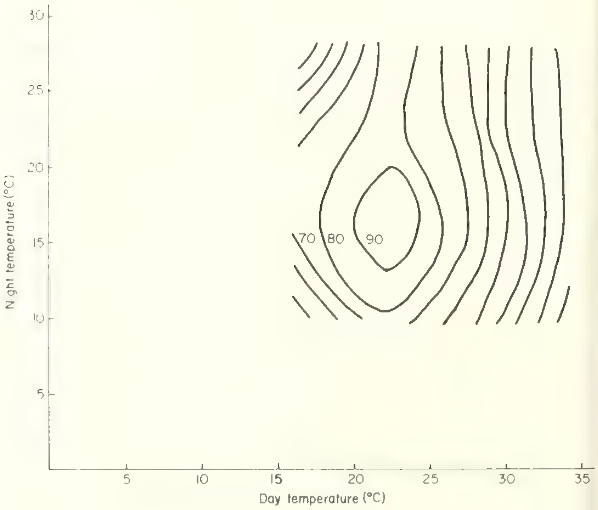
Species: *Picea glauca*
Growth Parameter: Caliper
Maximum Size (= 100%): 1.6mm
Seed Source: Central Alberta, DR-46135
Coefficient of Variability: 4.1%
Authority: Tinus (1976)



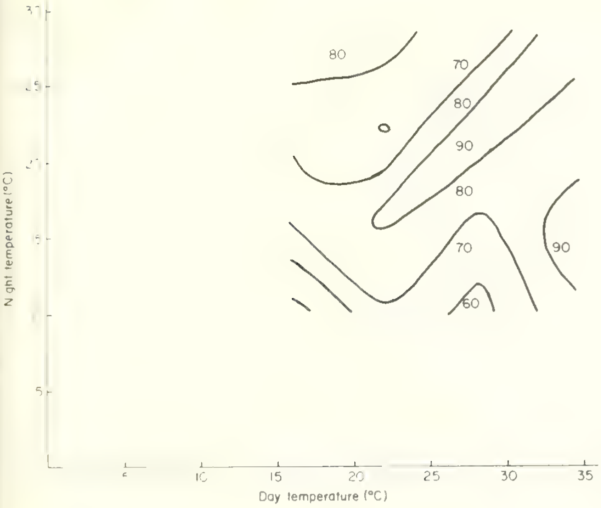
Species: *Picea glauca*
Growth Parameter: Height
Maximum Size (= 100%): 94mm
Seed Source: Central Alberta, DR-46135
Coefficient of Variability: 4.3%
Authority: Tinus (1976)



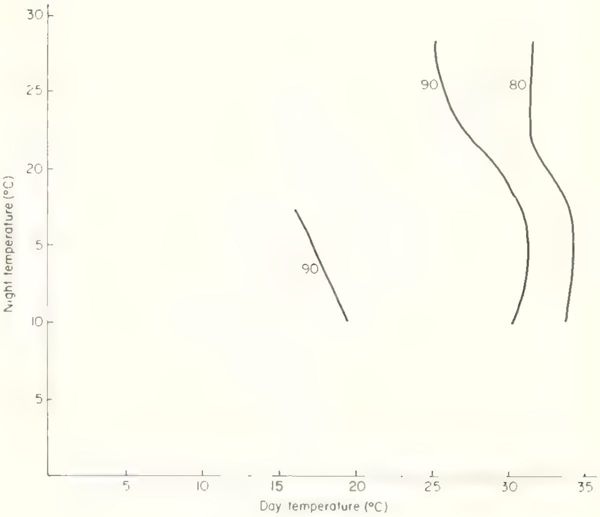
Species: *Picea glauca*
Growth Parameter: Dry weight
Maximum Dize (= 100%): 0.37gm
Seed Source: Central Alberta, DR-46135
Coefficient of Variability: 10.6%
Authority: Tinus (1976)



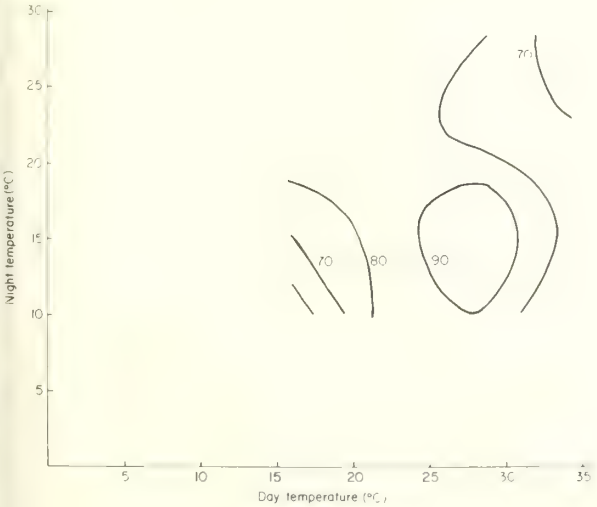
Species: *Picea glauca*
Growth Parameter: Root/shoot ratio (dry weight)
Maximum Size (= 100%): 0.23
Seed Source: Central Alberta , DR-46135
Coefficient of Variability: Not available
Authority: Tinus (1976)



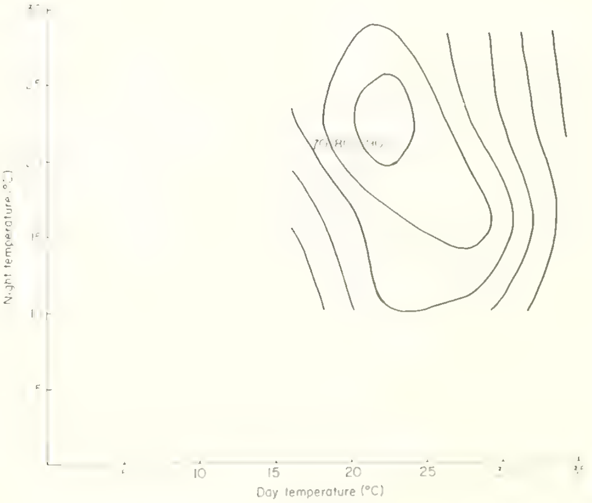
Species: *Picea glauca*
Growth Parameter: Caliper
Maximum Size (= 100%): 1.8mm
Seed Source: Central Alberta, DP-8796
Coefficient of Variability: 2.7%
Authority: Tinus (1976)



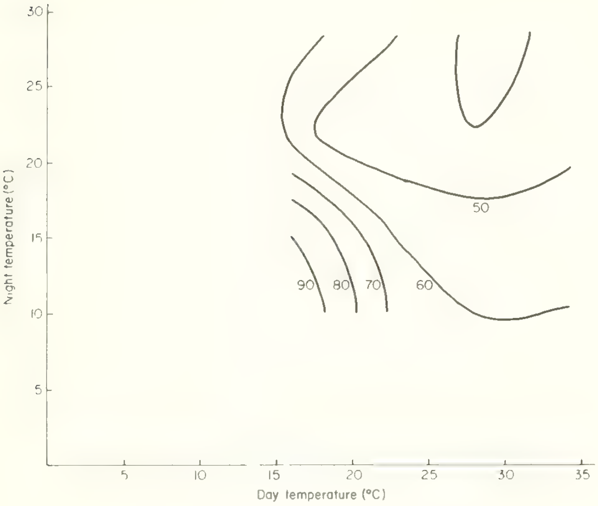
Species: *Picea glauca*
Growth Parameter: Height
Maximum Size (= 100%): 124mm
Seed Source: Central Alberta, DP-8796
Coefficient of Variability: 3.9%
Authority: Tinus (1976)



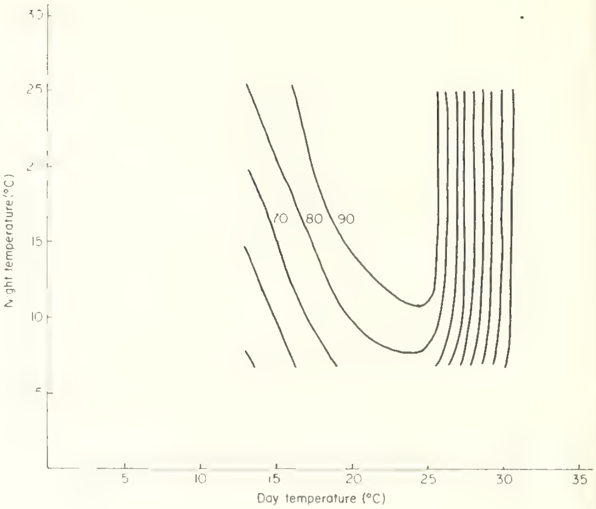
Species: *Picea glauca*
Growth Parameter: Dry weight
Maximum Size (= 100%): 0.56gm
Seed Source: Central Alberta, DP-8796
Coefficient of Variability: 6.6%
Authority: Tinus (1976)



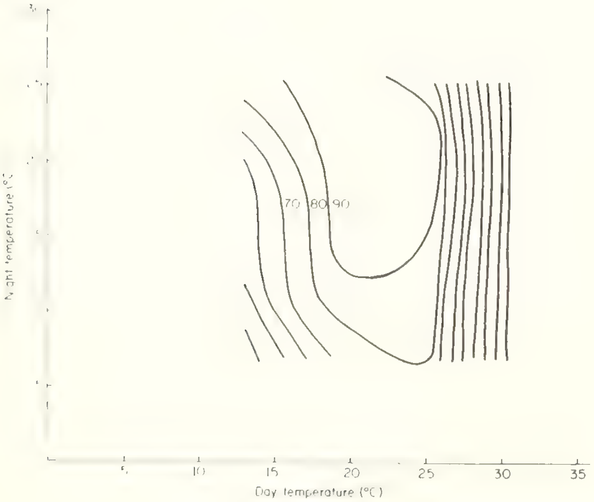
Species: *Picea glauca*
Growth Parameter: Root/shoot ratio (dry weight)
Maximum Size (= 100%): 0.43
Seed Source: Central Alberta, DP-8796
Coefficient of Variability: Not available
Authority: Tinus (1976)



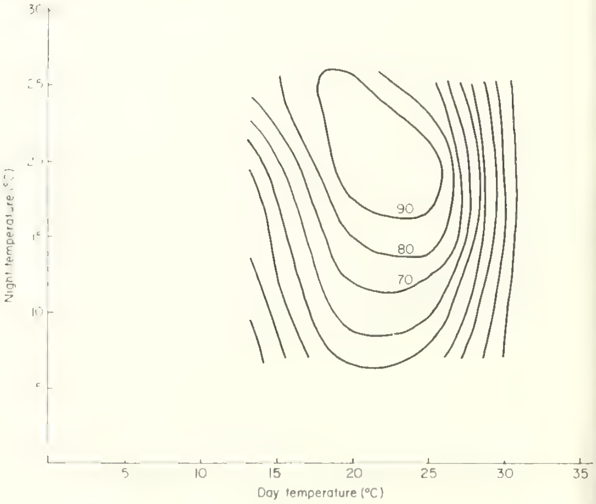
Species: *Picea pungens*
Growth Parameter: Caliper
Maximum Size (= 100%): 5.5mm
Seed Source: Indian Head, Sask. (origin unknown)
Coefficient of Variability: Not available
Authority: Tinus (1971)



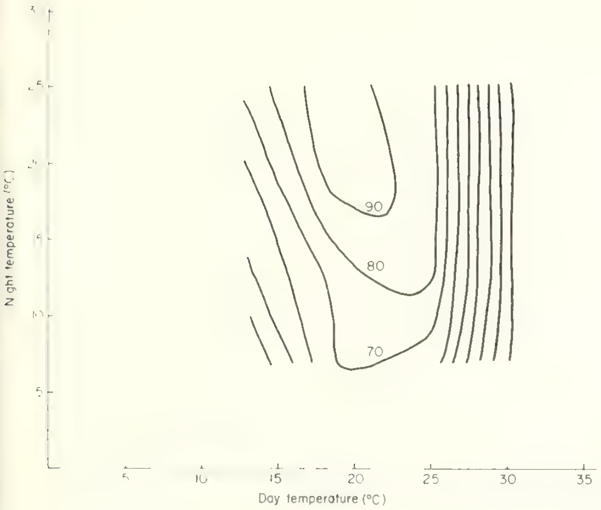
Species: *Picea pungens*
Growth Parameter: Height
Maximum Size (= 100%): 264mm
Seed Source: Indian Head, Sask. (origin unknown)
Coefficient of Variability: Not available
Authority: Tinus (1971)



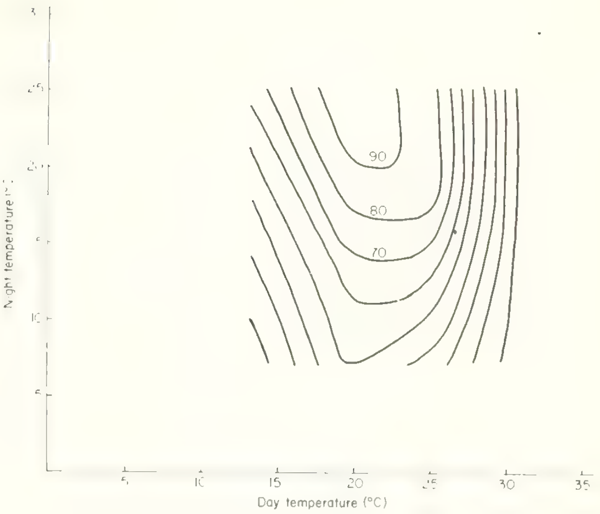
Species: *Picea pungens*
Growth Parameter: Dry weight
Maximum Size (= 100%): 8.9gm
Seed Source: Indian Head, Sask. (origin unknown)
Coefficient of Variability: Not available
Authority: Tinus (1971)



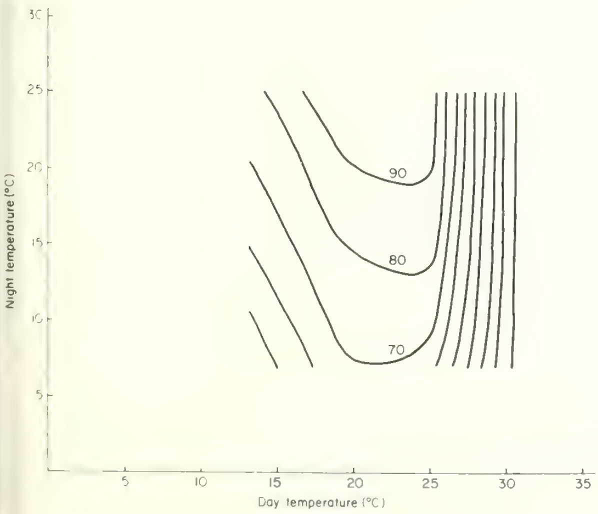
Species: *Picea pungens*
Growth Parameter: Height
Maximum Size (= 100%): 274mm
Seed Source: Fort Collins, Colo.
Coefficient of Variability: Not available
Authority: Tinus (unpublished)



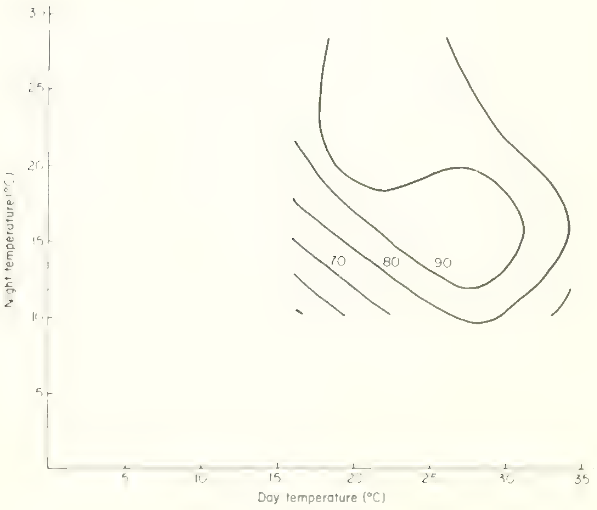
Species: *Picea pungens*
Growth Parameter: Dry weight
Maximum Size (= 100%): 9.4gm
Seed Source: Fort Collins, Colo.
Coefficient of Variability: Not available
Authority: Tinus (unpublished)



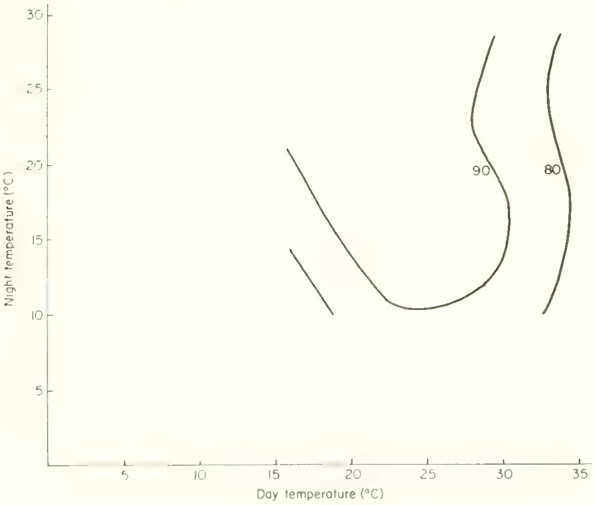
Species: *Picea pungens*
Growth Parameter: Caliper
Maximum Size (= 100%): 5.6mm
Seed Source: Fort Collins, Colo.
Coefficient of Variability: Not available
Authority: Tinus (unpublished)



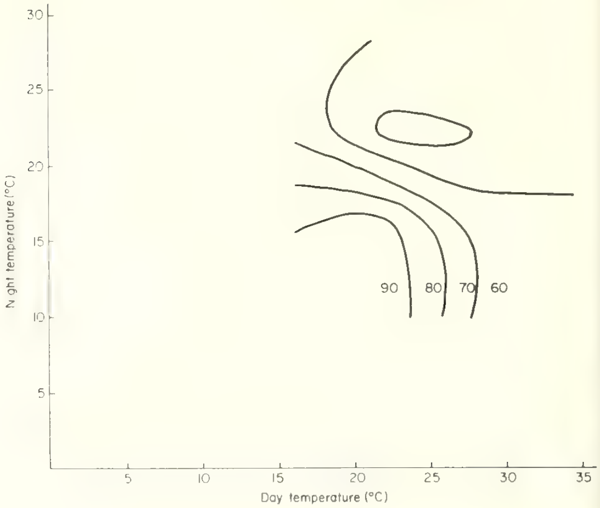
Species: *Pinus contorta*
Growth Parameter: Height
Maximum Size (= 100%): 113mm
Seed Source: Central Alberta, DB-655
Coefficient of Variability: 3.8%
Authority: Tinus (1976)



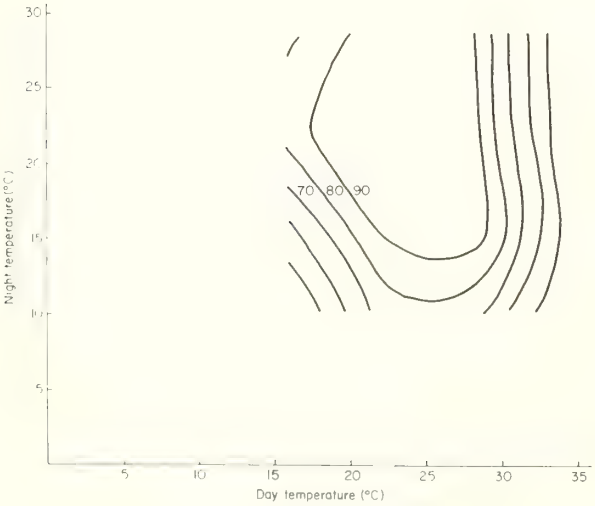
Species: *Pinus contorta*
Growth Parameter: Caliper
Maximum Size (= 100%): 1.8
Seed Source: Central Alberta, DB-655
Coefficient of Variability: 3.2%
Authority: Tinus (1976)



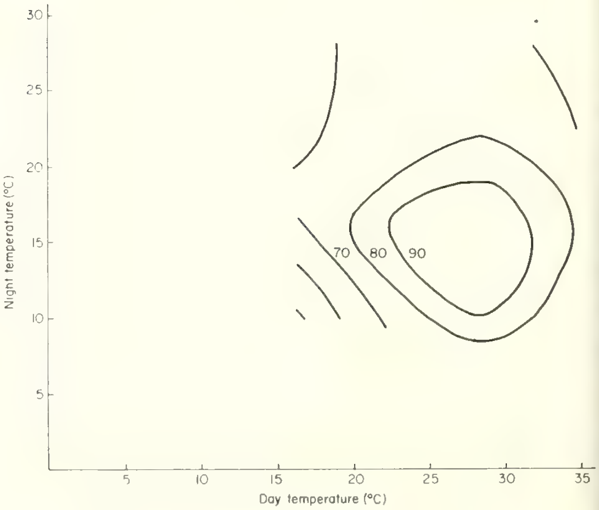
Species: *Pinus contorta*
Growth Parameter: Root/shoot ratio (dry weight)
Maximum Size (= 100%): 0.37
Seed Source: Central Alberta, DB-655
Coefficient of Variability: Not available
Authority: Tinus (1976)



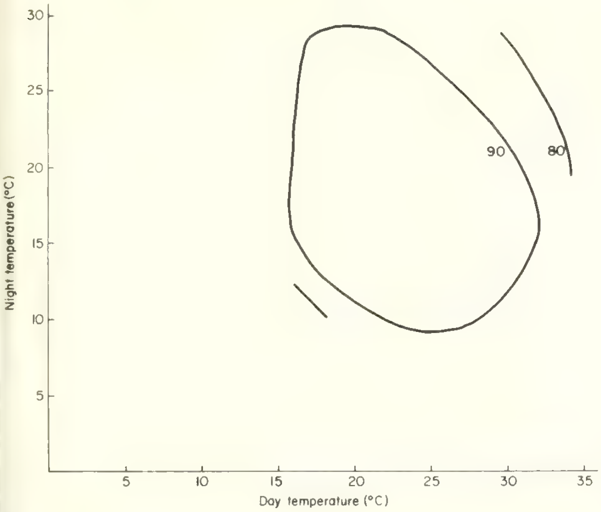
Species: *Pinus contorta*
Growth Parameter: Dry weight
Maximum Size (= 100%): 0.38gm
Seed Source: Central Alberta, DB-655
Coefficient of Variability: 7.0%
Authority: Tinus (1976)



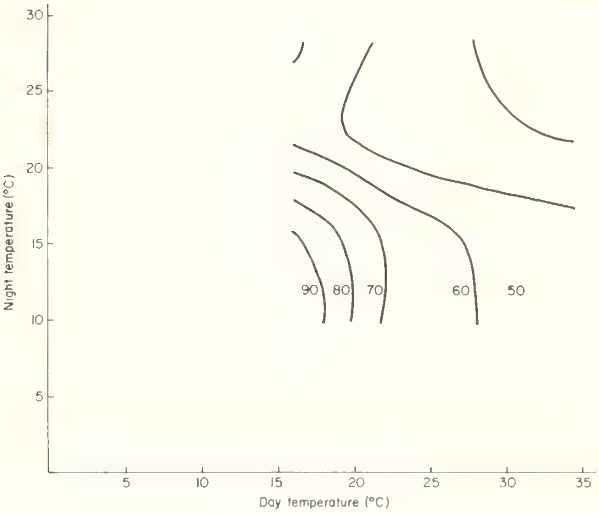
Species: *Pinus contorta*
Growth Parameter: Height
Maximum Size (= 100%): 117mm
Seed Source: Whitehorse, Y.T., L-236
Coefficient of Variability: 4.7%
Authority: Tinus (1976)



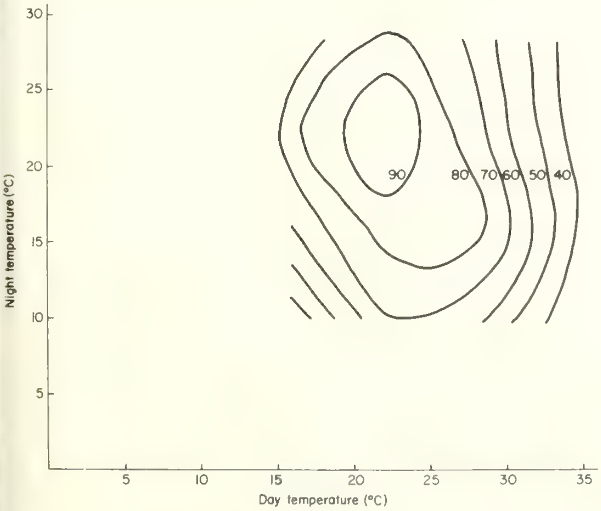
Species: *Pinus cortorta*
Growth Parameter: Caliper
Maximum Size (= 100%): 1.8mm
Seed Source: Whitehorse, Y.T., L-236
Coefficient of Variability: 3.6%
Authority: Tinus (1976)



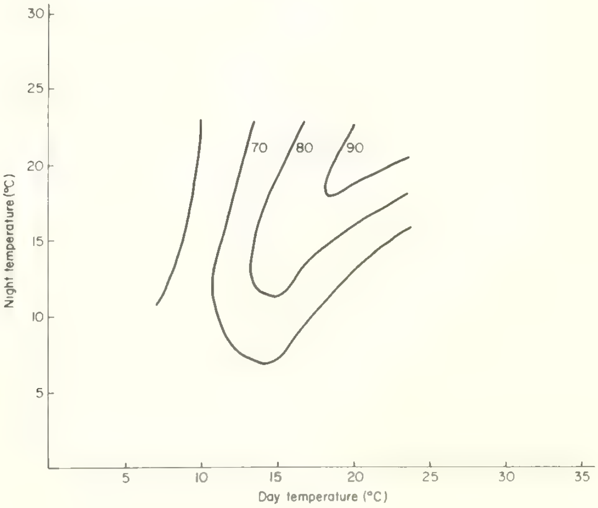
Species: *Pinus contorta*
Growth Parameter: Root/Shoot ratio (dry weight)
Maximum Size (= 100%): 0.54
Seed Source: Whitehorse, Y.T. L-236
Coefficient of Variability: Not available
Authority: Tinus (1976)



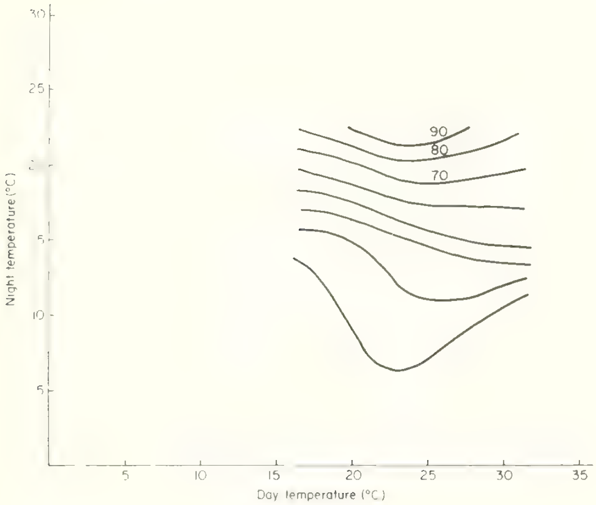
Species: *Pinus contorta*
Growth Parameter: Dry weight
Maximum Size (= 100%): 0.50gm
Seed Source: Whitehorse, Y.T., L-236
Coefficient of Variability: 8.5%
Authority: Tinus (1976)



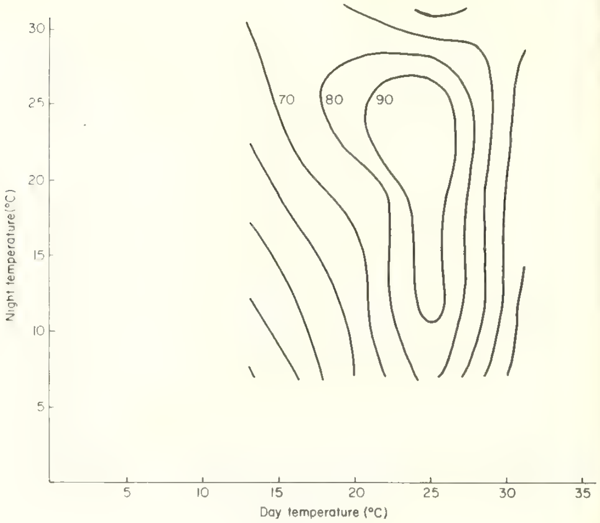
Species: *Pinus ponderosa*
Growth Parameter: Dry weight
Maximum Size (= 100%): 0.102gm
Seed Source: Black Hills, S. Dak.
Coefficient of Variability: Not available
Authority: Larson (1967)



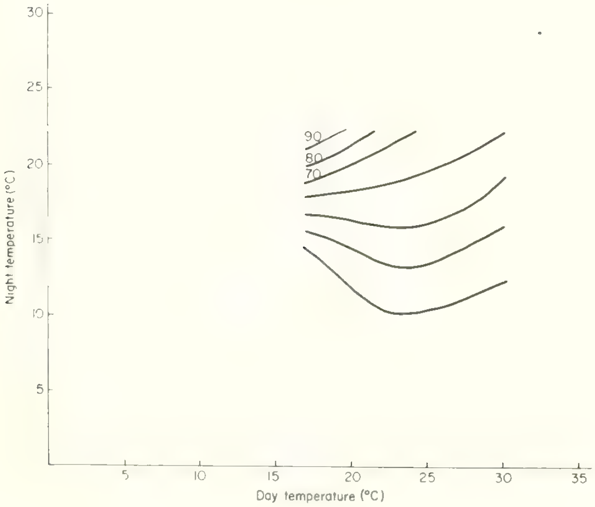
Species: *Pinus ponderosa*
Growth Parameter: Height
Maximum Size (= 100%): 43mm
Seed Source: Moon, S. Dak.
Coefficient of Variability: 20%
Authority: Callaham (1962)



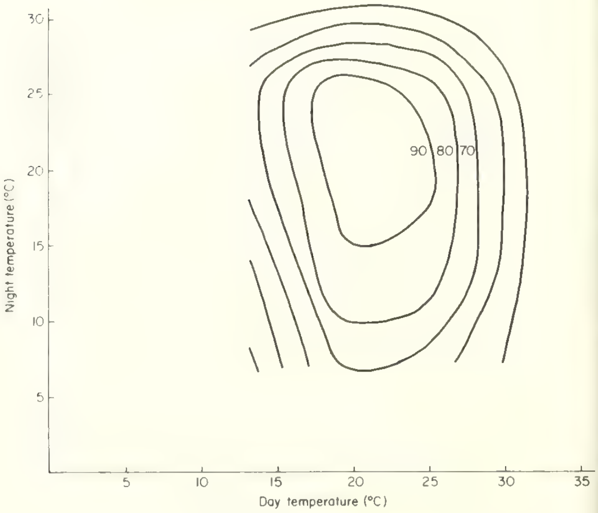
Species: *Pinus ponderosa*
Growth Parameter: Height
Maximum Size (= 100%): 147mm
Seed Source: Valentine, Nebr.
Coefficient of Variability: 5.4%
Authority: Tinus (1971)



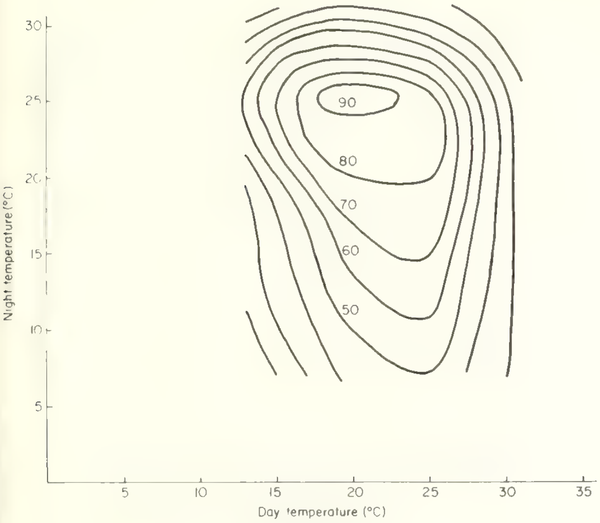
Species: *Pinus ponderosa*
Growth Parameter: Height
Maximum Size (= 100%): 67mm
Seed Source: Safford, Ariz.
Coefficient of Variability: 14%
Authority: Callaham (1962)



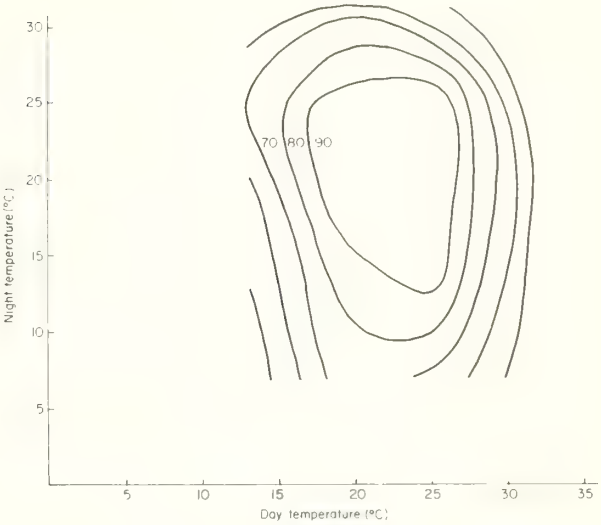
Species: *Pinus ponderosa*
Growth Parameter: Caliper
Maximum Size (= 100%): 7.6mm
Seed Source: Valentine, Nebr.
Coefficient of Variability: 4.3%
Authority: Tinus (1971)



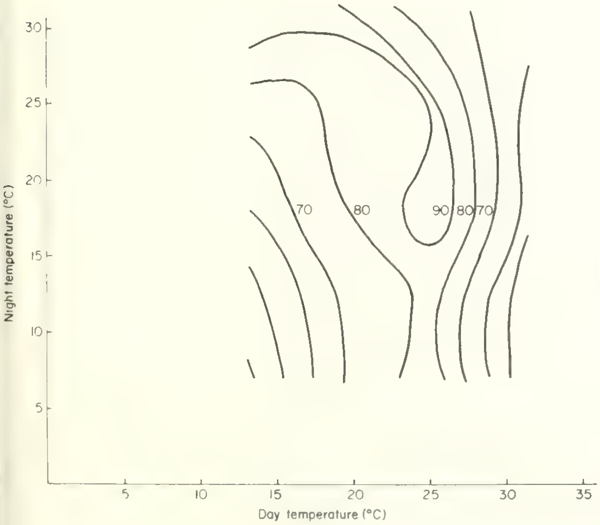
Species: *Pinus ponderosa*
Growth Parameter: Dry weight
Maximum Size (= 100%): 16.2gm
Seed Source: Valentine, Nebr.
Coefficient of Variability: 9.6%
Authority: Tinus (1971)



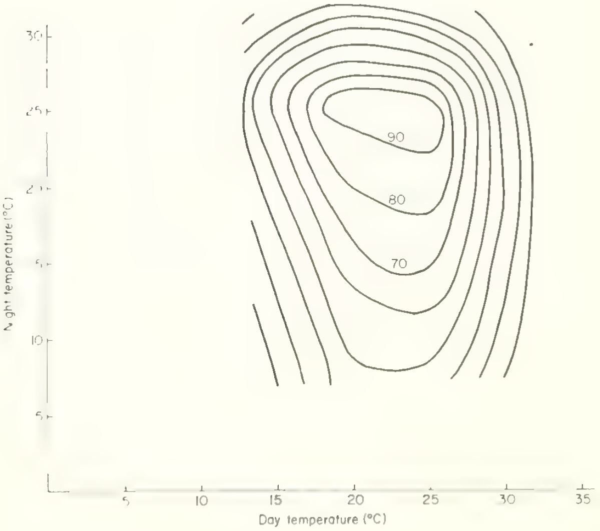
Species: *Pinus ponderosa*
Growth Parameter: Caliper
Maximum Size (= 100%): 8.7mm
Seed Source: Ruidoso, N. Mex.
Coefficient of Variability: 4.5%
Authority: Tinus (1971)



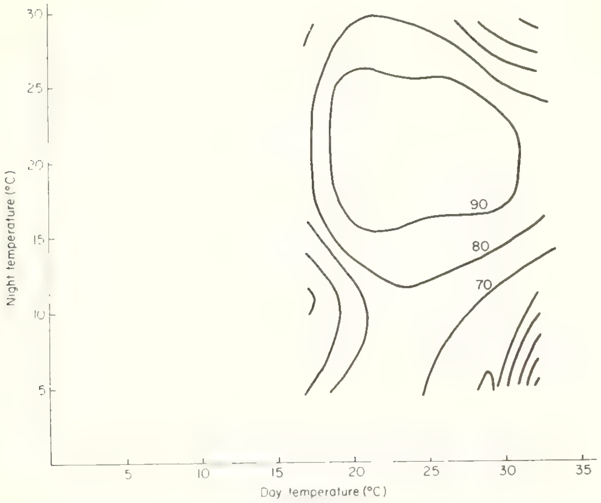
Species: *Pinus ponderosa*
Growth Parameter: Height
Maximum Size (= 100%): 154mm
Seed Source: Ruidoso, N. Mex.
Coefficient of Variability: 5.5%
Authority: Tinus (1971)



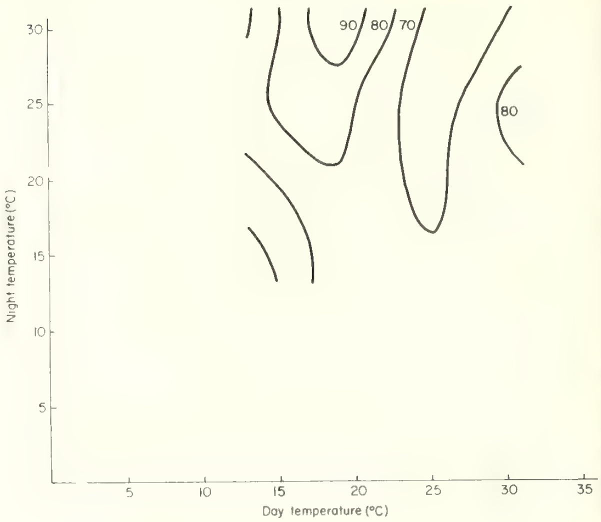
Species: *Pinus ponderosa*
Growth Parameter: Dry weight
Maximum Size (= 100%): 19.1gm
Seed Source: Ruidoso, N. Mex.
Coefficient of Variability: 8.4%
Authority: Tinus (1971)



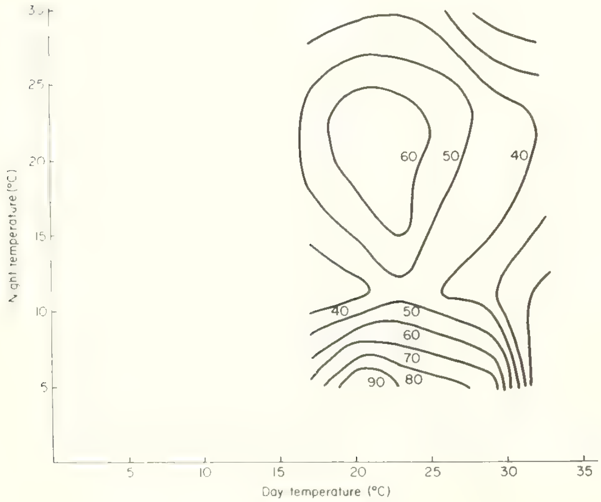
Species: *Pinus radiata*
Growth Parameter: Height
Maximum Size (= 100%): 386mm
Seed Source: Tallaganda Seed Orchard, Canberra
Coefficient of Variability: Not available
Authority: Cremer (1968)



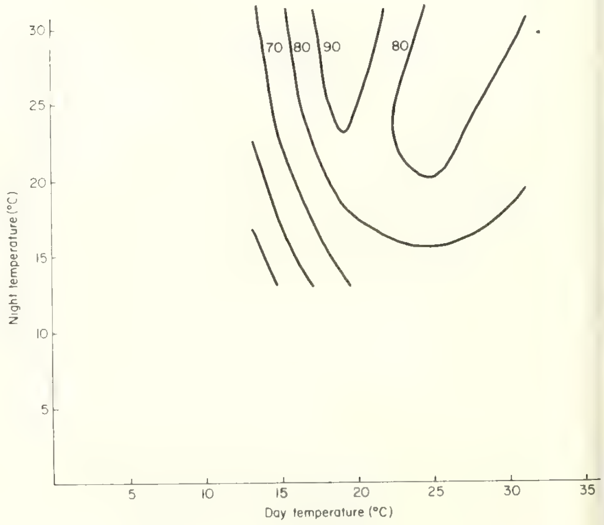
Species: *Pinus sylvestris*
Growth Parameter: Height
Maximum Size (= 100%): 191mm
Seed Source: Denbigh N. Dak. (Russian origin 645-21)
Coefficient of Variability: 5.5%
Authority: Tinus (unpublished)



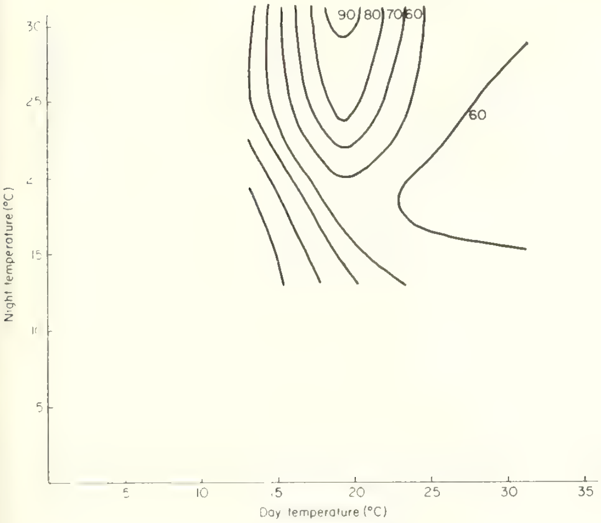
Species: *Pinus radiata*
Growth Parameter: Dry weight
Maximum Size (= 100%): 12.9gm
Seed Source: Tallaganda Seed Orchard, Canberra
Coefficient of Variability: Not available
Authority: Cremer (1968)



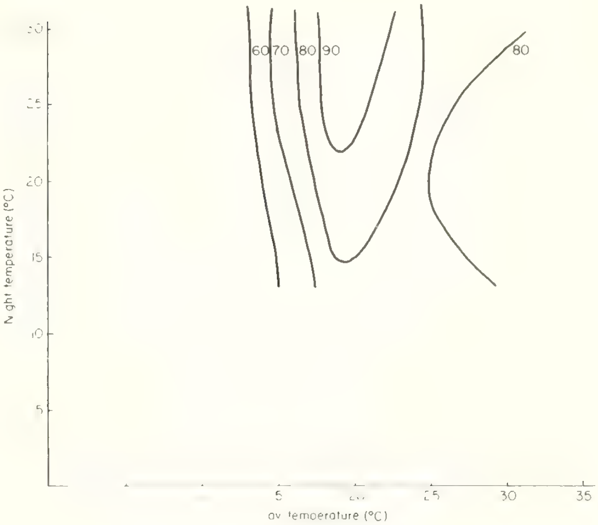
Species: *Pinus sylvestris*
Growth Parameter: Caliper
Maximum Size (= 100%): 5.6mm
Seed Source: Denbigh, N. Dak. (Russian origin 645-21)
Coefficient of Variability: 3.7%
Authority: Tinus (unpublished)



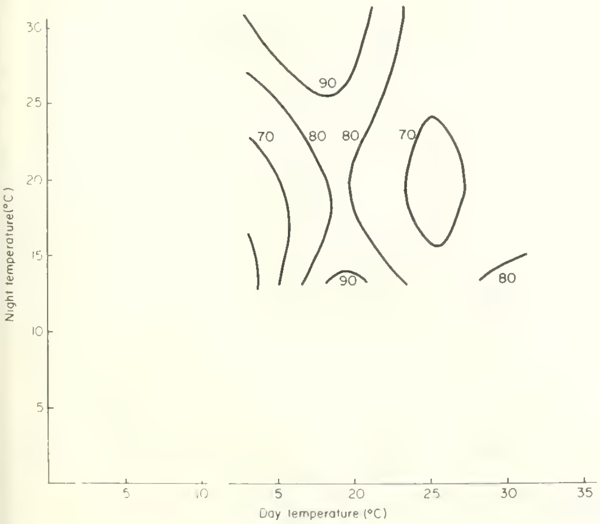
Species: *Pinus sylvestris*
Growth Parameter: Dry weight
Maximum Size (= 100%): 9.1gm
Seed Source: Denbigh, N. Dak. (Russian origin 645-21)
Coefficient of Variability: 9.8%
Authority: Tinus (unpublished)



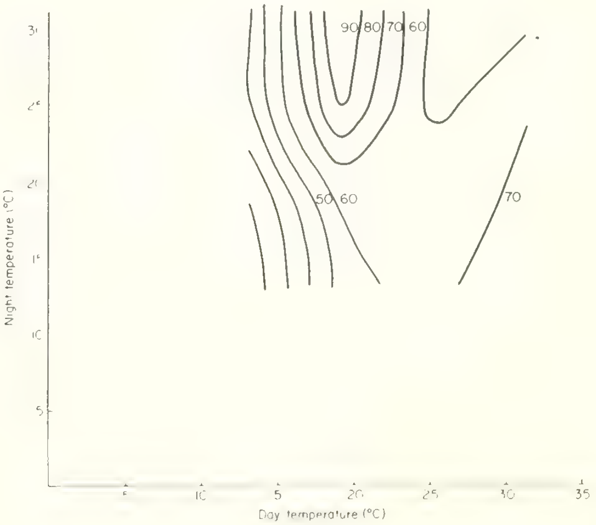
Species: *Pinus sylvestris*
Growth Parameter: Caliper
Maximum Size (= 100%): 5.1mm
Seed Source: Denbigh, N. Dak. (Russian origin 1940-21)
Coefficient of Variability: 4.1%
Authority: Tinus (unpublished)



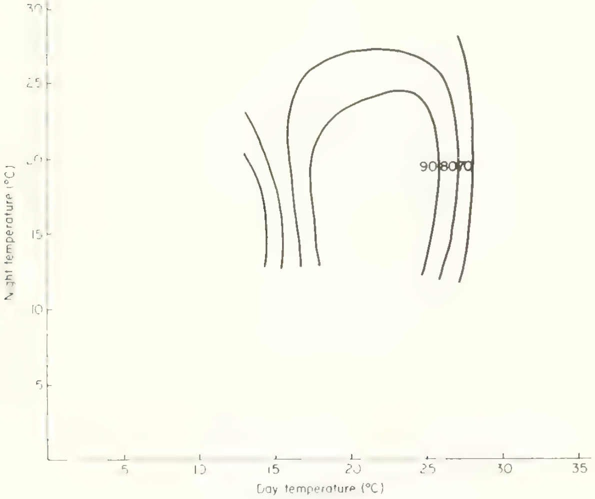
Species: *Pinus sylvestris*
Growth Parameter: Height
Maximum Size (= 100%): 158mm
Seed Source: Denbigh N. Dak. (Russian origin 1940-21)
Coefficient of Variability: 5.5%
Authority: Tinus (unpublished)



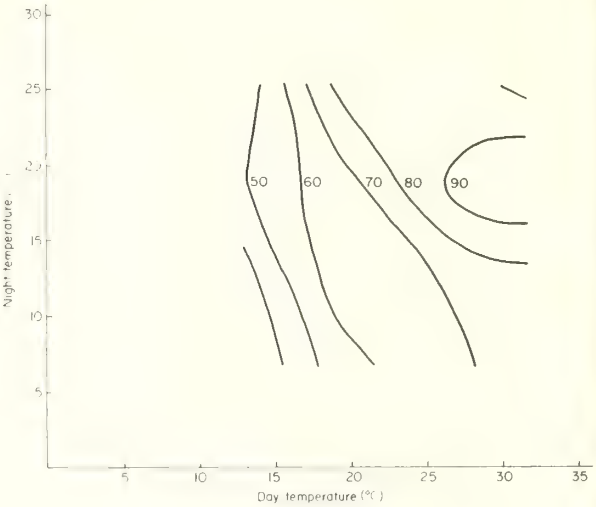
Species: *Pinus sylvestris*
Growth Parameter: Dry weight
Maximum Size (= 100%): 7.1gm
Seed Source: Denbigh, N. Dak. (Russian origin 1940-21)
Coefficient of Variability: 7.8%
Authority: Tinus (unpublished)



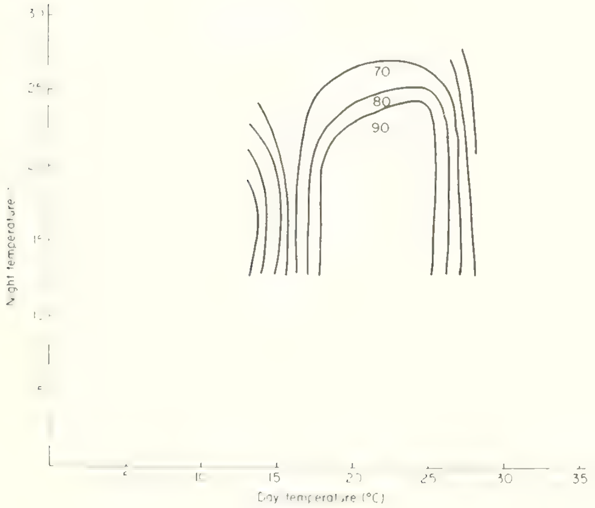
Species: *Pseudotsuga menziesii*
Growth Parameter: Height
Maximum Size (= 100%): 170mm
Seed Source: Lake Cowichan District, Vancouver Island
Coefficient of Variability: Not available
Authority: Brix (1971)



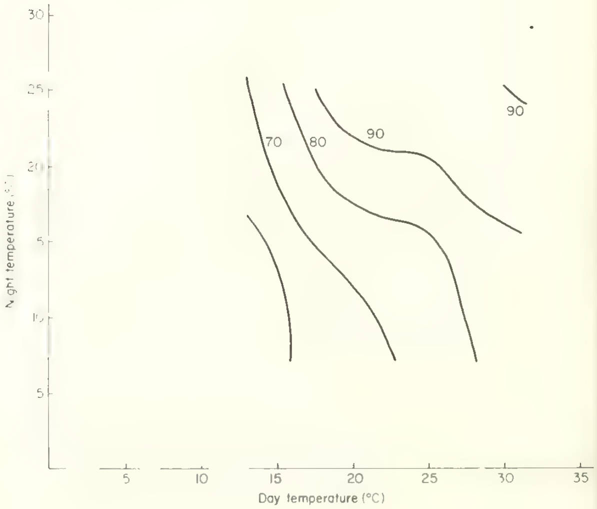
Species: *Quercus macrocarpa*
Growth Parameter: Height
Maximum Size (= 100%): 354mm
Seed Source: Devils Lake, N. Dak.
Coefficient of Variability: 5.6%
Authority: Tinus (1974)



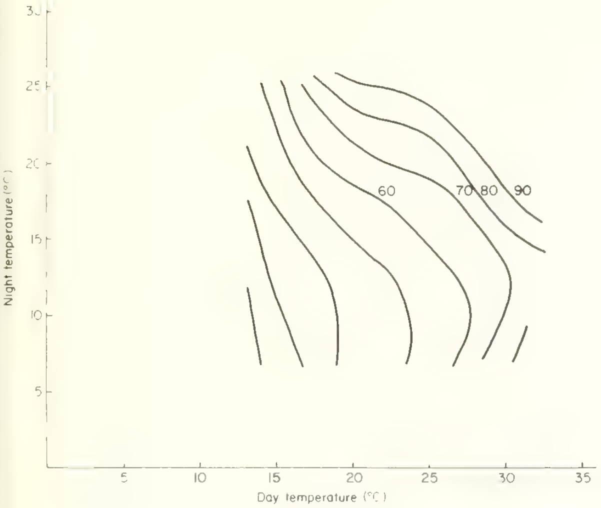
Species: *Pseudotsuga menziesii*
Growth Parameter: Dry weight
Maximum Size (= 100%): 2.4gm
Seed Source: Lake Cowichan District, Vancouver Island
Coefficient of Variability: Not available
Authority: Brix (1971)



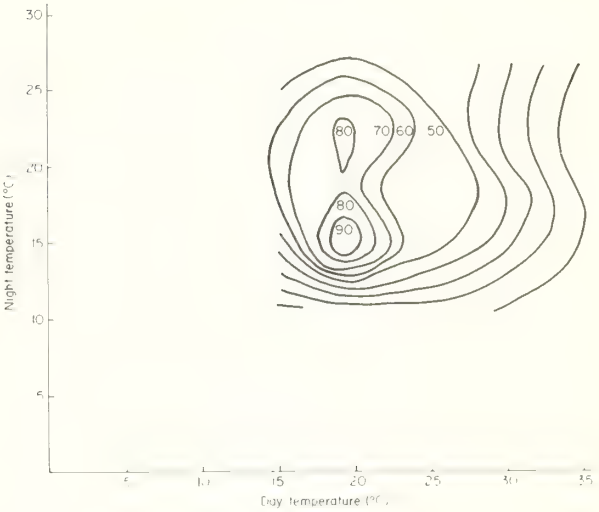
Species: *Quercus macrocarpa*
Growth Parameter: Caliper
Maximum Size (= 100%): 5.1mm
Seed Source: Devils Lake, N. Dak.
Coefficient of Variability: 5.5%
Authority: Tinus (1974)



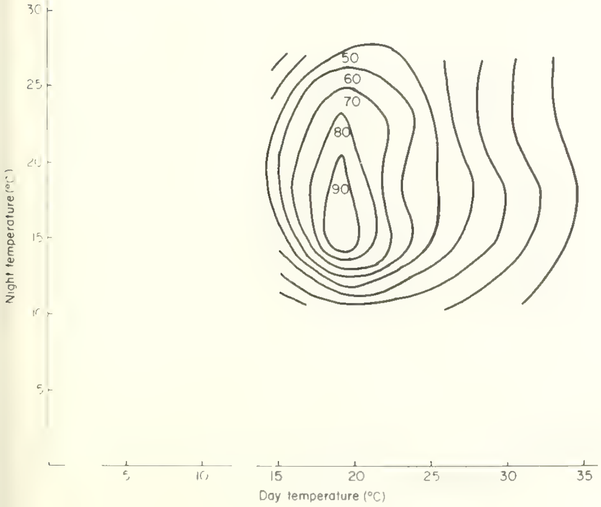
Species: *Quercus macrocarpa*
Growth Parameter: Dry weight
Maximum Size (= 100%): 7.2gm
Seed Source: Devils Lake, N. Dak.
Coefficient of Variability: 13.5%
Authority: Tinus (1974)



Species: *Sequoia sempervirens*
Growth Parameter: Dry weight
Maximum Size (= 100%): 29gm
Seed Source: Klamath, Calif.
Coefficient of Variability: 14%
Authority: Helmers (1966)



Species: *Sequoia sempervirens*
Growth Parameter: Height
Maximum size (= 100%): 810mm
Seed Source: Klamath, Calif.
Coefficient of Variability: 10%
Authority: Helmers (1966)



Appendix 2

Growing schedules were developed for a number of nurseries. These may be useful as a starting point for other nurseries to formulate their own growing schedules, but unless circumstances match closely, they should not be used without appropriate modification. The schedules are arranged in the following order:

Species	Container Size *(cu. in.)*	Nursery location	Outplanting time
Blue spruce	30	Fort Collins, Colo.	Spring
Douglas-fir	30	Fort Collins, Colo.	Spring
Engelmann spruce	30	Denver, Colo.	Spring
White spruce	10	Palmer, Alaska	Spring
Ponderosa pine	4	Bozeman, Mont.	Spring/Fall
Ponderosa pine	4	Bozeman, Mont.	Spring
Ponderosa pine	10	Salt Lake City, Utah	Spring
Scots pine	10	Salt Lake City, Utah	Spring
Austrian pine	10	Salt Lake City, Utah	Spring
Ponderosa pine	10	Salt Lake City, Utah	Spring/Fall
Scots pine	10	Salt Lake City, Utah	Spring/Fall
Austrian pine	10	Salt Lake City, Utah	Spring/Fall
Ponderosa pine	30	McNary, Ariz.	July-September
Rocky Mountain juniper	30	Manhattan, Kans.	Spring/Fall
Eastern redcedar	30	Manhattan, Kans.	Spring/Fall
Austrian pine	30	Manhattan, Kans.	Spring/Fall
Ponderosa pine	30	Manhattan, Kans.	Spring/Fall
Black walnut	30	Manhattan, Kans.	Spring/Fall
Black walnut	30	Carbondale, Ill.	Spring/Summer/Fall
Bur oak	30	Bismarck, N. Dak.	Spring
Slash pine Loblolly pine Longleaf pine	4	Pineville, La.	Spring/Summer/Fall
Douglas fir	3-10	Corvallis, Oreg.	Fall/Winter/Spring

Species Blue spruce & Douglas-fir **Container** 30 cubic inches **Outplanting** Spring **Location** Fort Collins, Colo. **Cycle** Summer (1/yr.) Info. Grade A

Source Colo.

Season		APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.
Growth stage		Germination	Juvenile growth	Exponential growth			Spruce 6-8'' tall		Spruce 12-16'' tall	Stage I Bud set	Hardening Caliper growth	Stage II Cold hardening Meet chilling requirements	Maintain dormancy and hardiness	
Day temp (°F)	**Optimum**	70	72	72						65		34	34	
	Permissible	65-75	64-77	64-77						55-70		30-50	30-60	
Night temp (°F)	**Optimum**	70	66	66						55		34	34	
	Permissible	65-75	63-73	63-73						50-60		30-45	30-45	
Rel. Hum. (%)	**Optimum**	80	60	60						50			50	
	Permissible	60-90	50-80	50-80						40-70			40-70	
Daylight		75% Sunlight. Add shade if necessary to keep temp below 85°								75% Sunlight. Add shade if needed to maintain temperature.			30% Sunlight	
Supplemental light		10 watts/ft² incandescent or equivalent at least 6% of the time at night No dark period over 15 min.								None				
Water		Frequent, light, surface always wet.	As needed. Water in excess each time. Surface should dry between waterings. Keep rootball near field capacity.							Leach with water. Dry to wilting. As needed as before.				
Fertilizer		None	Complete, high N, pH 5.5-6.0, EC 1,800 ±300 μmhos. Rinse foliage.							None Complete, low N, high PK. Rinse foliage.				
CO_2 level		Normal atmos.	1,000-1,500 ppm whenever vents are closed during daylight hours.									Normal atmosphere		
Operations		Fill, seed, load ghs.	Apply fungicide if needed.	Thin Do **not** transplant spruce.									Move to shadehouse. Ship anytime →	

Species Engelmann spruce **Container** 30 cubic inches **Outplanting** Spring (in mts.) **Location** Denver, Colo. **Cycle** Summer (1/yr.) Info. Grade A

Source Central Colo.

Season	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
Growth stage	Germination	Juvenile growth		Exponential growth		Trees 12-16'' tall Bud set	Natural hardening Caliper growth		Cold hardening	Chilling requirements met		Maintain dormancy and hardiness	
Day temp (°F) Optimum	70	66		66			66		34				34
Day temp (°F) Permissible	65-75	63-74		63-74			60-75		30-50				30-60
Night temp (°F) Optimum	70	73		73			60		34				34
Night temp (°F) Permissible	65-75	71-75		71-75			50-65		30-45				20-45
Rel. Hum. (%) Optimum	80	60		60			60						
Rel. Hum. (%) Permissible	60-90	50-80		50-80			50-80						
Daylight	30% Sunlight (2 layers poly, 1 shade cloth)		60% Sunlight (2 layers poly.) Increase shade to hold temp. or if chlorosis appears.			50% Sunlight (shadehouse)					Bright skylight desirable. Direct sun or total darkness not desirable.		
Supplemental light	8 watts/ft² incandescent or equivalent at least 6% of the time at night. No dark period over 15 min.						None						
Water	Frequent light, surface always wet	As needed with nutrient solution Water in excess each time. Surface should dry between waterings. Keep rootball near field capacity.			Leach with water. Do not dry		As needed as before.						
Fertilizer	None	Complete, high N, pH 5.5-6.0, EC 1,800 ±300 μmhos.				None	Complete, low N, high PK.						
CO_2 level	None	1,000-1,500 ppm whenever vents are closed during daylight hours.					None						
Operations	Fill, seed, load ghs. Apply fungicide if needed.		Thin Do **not** transplant.				Move to shadehouse. Mulch with sawdust				May be moved to ranger district and mulched anytime after Dec 1, or remain in shadehouse		

Species White spruce **Container** 10 cubic inches **Outplanting** Spring **Location** Palmer, Alaska **Cycle** Summer (1/yr.) Info. Grade B

Source Fairbanks, Alaska

Season		MAR.	MAR.	APR. – MAY	MAY – AUG.	AUG.	SEPT. – MAR.	
Growth stage		Sow	Germination	Juvenile growth	Exponential growth		Natural hardening	Maintain dormancy
Day temp (°F)	**Optimum**		70	72	72		65 (declining with the season)	
	Permissible		65-75	68-75	68-75		55-70	
Night temp (°F)	**Optimum**		70	61	61		55	
	Permissible		65-75	56-72	56-72		50-70	
Rel. Hum. (%)	**Optimum**		80	60				
	Permissible		60-90	50-70				
Daylight			75% Sunlight (unshaded 2 layer ghs)				50% Sunlight (shadehouse)	
Supplemental light			8 watts/ft² incandescent light at least 6% of the dark period. No dark period over 15 min.				None	
Water			Frequent, light, surface always wet		As needed with nutrient solution Surface should dry Rootball always near field capacity.	Leach with water Dry to wilting.	As needed Treat as before.	
Fertilizer			None	Complete, high N, pH 5.5-6 0, EC 1,500-2,000 μmhos. Water in excess each time. Rinse foliage with water.		None	Complete, low N, high PK. Otherwise, as before.	
CO_2 level			Normal atmos.	1,000-1,500 ppm whenever vents are closed during daylight hours			None (Normal atmosphere)	
Operations		Fill, seed, load ghs.		Thin		Move trees to shadehouse.		Ship May 1

Species Ponderosa pine **Container** 4 cubic inches **Outplanting** Spring/Fall **Location** Bozeman, Mont. **Cycle** Summer (2/yrs.) Info. Grade

Source E. Mont.

Season		APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.
Growth stage		Germination	Juvenile growth	Mature foliage appears	Multiple flushing	Bud set	Natural hardening Caliper growth			Maintain dormancy and hardiness.				
Day temp (°F)	**Optimum**	70	72	72		65 (declining with the season)				34				
	Permissible	65-75	68-77	68-77		60-75				20-60				
Night temp (°F)	**Optimum**	70	75	75		55				34				
	Permissible	65-75	68-77	68-77		50-65				20-45				
Rel. Hum. (%)	**Optimum**	80	60			60								
	Permissible	60-90	50-80			50-80								
Daylight		50% Sunlight	75-90% Sunlight			30-50% Sunlight		Bright skylight only.						
Supplemental light		None	8 watts/ft² incandescent or equivalent at least 3% of the night time. No dark period over 30 min.			None								
Water		Frequent, light, surface always wet	As needed. Surface should dry. Water in excess. Keep rootball near field capacity.		Leach with water. Dry to wilting.	As needed as before.								
Fertilizer		None	Complete, high N, pH 5.5-6.0, EC 1,800±300 μmhos. Rinse foliage.			None	Complete, low N, high PK, pH 5.5-6.0, EC 1,800±300 μmhos. Rinse foliage.							
CO_2 level		Normal atmos.	1,000-1,500 ppm whenever vents are closed during daylight hours.			Normal atmosphere								
Operations		Load ghs. Apply fungicide if needed. Thin				Move to shadehouse.	Ship for fall planting							Ship and outplant

Species Ponderosa pine **Container** 4 cubic inches **Outplanting** Spring **Location** Bozeman, Mont. **Cycle** Winter (2/yr.) Info. Grade B

Source E. Mont.

Season		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.
Growth stage		Germination	Juvenile growth	Mature foliage appears	Multiple flushing		Stage Hardening Bud set Caliper growth		Stage II Cold hardening Meet chilling requirement	Maintain dormancy and hardiness				
									(Frost o k , but not a frozen rootball)					
Day temp (°F)	**Optimum**	70	72		72			65	34	34				
	Permissible	65-75	68-77		68-77			60-68	30-50	30-60				
Night temp (°F)	**Optimum**	70	75		75			55	34	34				
	Permissible	65-75	68-77		68-77			50-65	30-45	30-45				
Rel. Hum. (%)	**Optimum**	80	60		60				60					
	Permissible	60-90	50-80		50-80				50-80					
Daylight		50% Sunlight		75-90% Sunlight			75-90% Sunlight (Shade only to maintain temperature)			Bright skylight Sun not needed.				
Supplemental light		None	8 watts/ft² incandescent or equivalent at least 3% of the night time. No dark period over 30 min					None		None				
Water		Frequent, light, surface always wet	As needed. Water in excess each time. Surface should dry between waterings. Keep rootball near field capacity.				Leach with water Dry to wilting.	As needed as before.						
Fertilizer		None	Complete, high N, pH 5.5-6.0, EC 1,800±300 μmhos. Rinse foliage.				None	Complete, low N, high PK Rinse foliage.			Water with high N just before shipment			
CO_2 level		Normal atmos.	1,000-1,500 ppm whenever vents are closed during daylight hours.					None						
Operations		Load ghs. Apply fungicide if needed.	Thin							Move to shadehouse. Ship and outplant				

Species Ponderosa pine
Scots pine
Austrian pine **Container** 10 cubic inches **Outplanting** Spring **Location** Salt Lake City, Utah **Cycle** Winter (2/yr.) Info. Grade B

Source

Season		AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.
Growth stage		Germination	Juvenile growth	Mature foliage appears	Multiple flushing			Stage I Hardening Bud set Caliper growth	Stage II Cold hardening Meet chilling requirements	Maintain dormancy and hardiness		Top flush after outplanting		
Day temp (°F)	**Optimum**	70	72		72			65	34	34				
	Permissible	65-75	65-80		65-85			60-70	33-50	20-60				
Night temp (°F)	**Optimum**	70	75		75			55	34	34				
	Permissible	65-75	68-77		68-77			50-65	33-40	20-45				
Rel. Hum. (%)	**Optimum**	80	60		60			60	60	60				
	Permissible	60-90	50-80		50-80			50-80	50-80	50-80				
Daylight		40-50% Sunlight		75-90% Sunlight					30% Sunlight or bright skylight	Skylight only (can do without any)		Partial shade if available		
Supplemental light		None	8 watts/ft² incandescent or equivalent at least 3% of the time No dark period over 30 min				None		None	None				
Water		Frequent, light, surface always wet	As needed. Surface should dry Water in excess each time Keep rootball near field capacity			Leach with water Dry to wilting		As needed treat as before						
Fertilizer		None	Complete, high N, pH 5 5-6 0 EC 1,800±300 μmhos Rinse foliage				None	Complete, low N, high PK Rinse foliage		Water with high N just before shipment				
CO_2 level		Normal atmos	1,000-1,500 ppm whenever vents are closed during daylight hours						Normal atmosphere					
Operations		Load ghs	Thin				Begin Stage I hardening when trees are as tall as desired No later than Jan 24			Move crop to shadehouse or cooler Ship and outplant				

Species Ponderosa pine
Scots pine
Austrian pine **Container** 10 cubic inches **Outplanting** Spring/Fall **Location** Salt Lake City, Utah **Cycle**

Source

Season		APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.
Growth stage		Germination	Juvenile growth	Mature foliage appears	Multiple flushing	Bud set	Natural hardening Caliper growth	Cold hardening	Chilling requirements met			Maintain dormancy and hardiness.		
Day temp (°F)	**Optimum**	70	72	72		65	(declining with the season)						34	
	Permissible	65-75	65-80	65-85		50-80					(Minimum rootball temp. 0° F)		10-50	
Night temp (°F)	**Optimum**	70	75	75		60							34	
	Permissible	65-75	68-77	68-77		40-65							10-45	
Rel. Hum. (%)	**Optimum**	80	60	60										
	Permissible	60-90	50-80	50-80			Same							
Daylight		40-50% Sunlight	75-90% Sunlight				50% Sunlight							
Supplemental light		None	8 watts/ft² incandescent or equivalent at least 3% of the night time. No dark period over 30 min.			None								
Water		Frequent, light, surface always wet	As needed. Surface should dry. Water in excess each time. Keep rootball near field capacity.			Fall planting. Leach with water. Dry to wilting. Spring planting. Omit drydown. As needed. Treat as before.								
Fertilizer		None	Complete, high N at each watering. Rinse foliage.			None	Complete, low N, high PK							
CO$_2$ level		Normal atmos.	1,000-1,500 ppm whenever vents are closed during daylight hours.				Normal atmosphere							
Operations		Load ghs.	Apply fungicide if needed Thin			Move to shadehouse. Mulch with sawdust	Ship for fall planting						Move to a cooler to prevent budbreak. Ship for spring planting.	

Protect crop from excessive winter rain

Species Ponderosa pine **Container** 30 cubic inches **Outplanting** July-Sept. **Location** McNary, Ariz. **Cycle** Spring (1/yr.) Info. Grade A

Source Central Ariz.

Season		JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.
Growth stage		Germination	Juvenile growth	Mature foliage appears	Multiple flushing		Stage I Hardening Bud set Caliper growth	Root growth after outplanting Terminal growth unlikely						
Day temp (°F)	**Optimum**	70	72		72		70							
	Permissible	60-78	65-80		65-80		50-80							
Night temp (°F)	**Optimum**	70	72		75		60							
	Permissible	60-75	55-75		64-77		50-65							
Rel. Hum. (%)	**Optimum**	80	60		60		60							
	Permissible	60-90	50-80		50-80		30-80							
Daylight		75% Sunlight Shade if necessary		75-90% Sunlight, shade only if necessary to maintain permissible temperatures			Bright skylight or 30% Sunlight							
Supplemental light		None	8 watts/ft² incandescent light or equivalent at least 3% of the night time. No dark period over 30 min				None							
Water		Frequent, light, surface always wet	As needed. Surface should dry. Water with nutrient solution in excess each time. Keep rootball near field capacity			Leach with water. Dry to wilting.	As needed treat as before							
Fertilizer		None	Complete, high N, pH 5.5-6.0, EC 1,800±300 μmhos Rinse foliage				None Complete, low N, high PK	Water with high N just before shipment						
CO$_2$ level		Normal atmos	1,000-1,500 ppm whenever vents are closed during daylight hours				Normal atmosphere							
Operations		Load ghs	Thin Apply fungicide if needed			Move to shade-house		Ship and outplant						

Species Rocky Mtn. juniper, Eastern redcedar
Austrian pine
Ponderosa pine
Black walnut **Container** 30 cubic inches **Outplanting** Spring/Fall **Location** Manhattan, Kans. **Cycle** Initial 1st and 2nd Info. Grade

Source ______

Season	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.
Growth stage	Germination Juniper	Walnut Pine	Walnut full size						Stage I Hardening pine, juniper Walnut continues growth				
Day temp (°F) Optimum	75		78			Greenhouse same			75				
Day temp (°F) Permissible	65-80		70-85						65-85				
Night temp (°F) Optimum	50	72							60				
Night temp (°F) Permissible	45-60	65-75							50-65				
Rel. Hum. (%) Optimum	80	60							50				
Rel. Hum. (%) Permissible	60-90	50-80							30-80				
Daylight	50% Sunlight	75-90% Sunlight							50% Sunlight (Sunlight shadehouse)				
Supplemental light	10 watts/ft² incandescent or equivalent at least 1 part in 15 throughout the night Dark periods longer than 15 min.								None				
Water	Frequent, light, surface always moist		As needed, according to species Water in excess each time. Surface should dry between waterings Keep rootball near field capacity						Leach pine and juniper with water. As needed as before				
Fertilizer	None	Juniper only	Pine Walnut	Complete, high N, pH 5.5-6.0, EC 1,800±300 μmhos. Rinse foliage.					None	Complete, low N. Rinse foliage.			
CO$_2$ level	Normal atmosphere	1,000-1,500 ppm whenever vents are closed during daylight hours							Normal atmosphere				
Operations	X-Plant juniper X-Plant pine and walnut								Move pine, juniper to shadehouse			Ship for fall planting or hold for spring planting.	
		Apply fungicide if needed	Thin pine and juniper	Walnut options: A. Keep in greenhouse B. Move Crop #1 to heated storage. X Start Crop #2			Move walnut Crops 1 and 2 to shadehouse and ship.	X Plant walnut Crop #3.		Move walnut Crop #3 to shadehouse.			

Species Black walnut **Container** 30 cubic inch **Outplanting** Spring/ Summer/Fall **Location** Carbondale, Ill **Cycle** ______

Source ______

Season		MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
Growth stage		Crop #1 X-Germinate seed X-Plant germinants	Crop #2 X-Germinate seed X-Plant germinants		Crop #3 X-Germinate seed X-Plant germinants	Crop #4 X-Germinate seed X-Plant germinants		Crop #5 X-Germinate seed X-Plant germinants		Crop #6 X-Germinate seed X-Plant germinants				Crop #1 X-Germinate seed X-Plant germinants
Day temp (°F)	**Optimum**		82								68	50	34	
	Permissible		79-86								65-77	33-60	30-50	
Night temp (°F)	**Optimum**		72								59	37	34	
	Permissible		66-82								55-66	33-41	30-37	
Rel. Hum. (%)	**Optimum**		60									60		
	Permissible		50-80									50-80		
Daylight		50-90% of full sunlight (2 layers polyethylene, no shade)			Same, but add 30% shade if needed to stay under maximum day temperature.			Same, but no shade			Same, but shade as needed to stay under maximum day temperature			
Supplemental light		8 watts/ft² incandescent light on 1 min out of every 15 min (or 6% of the time, provided no dark period is longer than 30 min) throughout the night									None			
Water		As needed. Surface should dry between waterings. Fertilize and water in excess at every watering. Maintain rootball moisture stress at 0.5-3 bars									Leach well Dry to wilting	As needed, as before		
Fertilizer		Complete, high N, pH 6.0-6.5. Conductivity 1,800 ±300 μmhos. Rinse foliage and piping									None	Complete, low N, high PK. Otherwise, same as before.		
CO_2 level		1,000-1,500 ppm whenever vents are closed during daylight hours.									Normal atmosphere			
Operations			X-Move Crop #1 to shadehouse		X-Move Crop #2 to shadehouse	X-Move Crop #3 to shadehouse		X-Move Crop #4 to shadehouse	X-Crop #5 to shadehouse					X-Crop #6 to shadehouse or
				X-Ship & plant Crop #1		X-Ship Crop #2	X-Ship Crop #3		X-Ship Crop #4	X-Ship Crop #5				X-Ship & plant

Species Bur oak **Container** 30 cubic inches **Outplanting** Spring **Location** Bismark, N. Dak. **Cycle** 2 crops per year. Info. Grade A

Source

Season		MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
Growth stage		Germination	Juvenile growth	Multiple flushing	Crop #1 Bud set Germinate Crop #2	Juvenile growth	Multiple flushing		Natural hardening Bud set, leaf fall	Cold hardening meet chilling requirements		Maintain dormancy		
Day temp (°F)	**Optimum**	70	90		Crop #2 70		Crop #2 90		70	34		34		
	Permissible	68-80	80-95		68-80		80-95		60-80	32-40		28-50	(Rootball should not remain continuously frozen)	
Night temp (°F)	**Optimum**	70	72		70		72		55	34		34		
	Permissible	68-80	66-80		68-80		66-80		45-70	32-40		28-40		
Rel. Hum. (%)	**Optimum**	70	70		70		70		Same	Same		Same		
	Permissible	50-90	50-90		50-90		50-90		Same	Same		Same		
Daylight		50-90% of full Sunlight			Same		Same		Same	Same				
Supplemental light		None	8 watts/ft² incandescent light on 1 min. out of every 15 min. (or 6% of the time, provided no dark period is longer than 30 min.) throughout the night.						None					
Water		As needed. Surface should dry between waterings. Maintain rootball moisture stress at 0.5-3 bars. Fertilize (except during germination) and water in excess at every watering.							Same					
Fertilizer		None	Complete, high N, pH 5.8-6.8, conductivity 1,800 ±300 μmhos.		Crop #1: As before using low N, high PK. Crop #2: As before using high N.				Both crops receive low N, high PK.					
CO_2 level		Normal atmos.	1,000-1,200 ppm whenever vents are closed during daylight hours.		Normal atmos.	Crop #2: 1,000-1,200 ppm whenever vents are closed during daylight hours.			Normal atmosphere					
Operations		Germinate seed Plant seed			Move Crop #1 to shadehouse			Collect seed		Mulch Crop #1			Move Crop #2 to shadehouse	

Species Slash
Loblolly
Longleaf pine **Container** 4 cubic inches **Outplanting** Spring/
Summer/Fall **Location** Central La. **Cycle** 3 crops, 1 year Info. Grade B

Source Courtesy of James P. Barnett, Researcher Forester, Southern For. Exp. Stn. Pineville, La.

Season		OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.
Growth stage		Germination Crop #1 Juvenile growth	Exponential growth	Greenhouse hardening	Germination Crop #2	Juvenile growth	Exponential growth	Germination Crop #3	Juvenile growth	Exponential growth			
Day temp (°F)	**Optimum**	72 75	70	65	72	75	78	72	75	78			
	Permissible	65-80 65-85	72-85	55-70	65-80	65-85	72-85	65-80	65-85	72-85			
Night temp (°F)	**Optimum**	72 72	75	55	72	72	75	72	72	75			
	Permissible	65-80 65-80	72-85	50-65	65-80	65-80	72-85	65-80	65-80	72-85			
Rel. Hum. (%)	**Optimum**	80	60		80		60	80	60				
	Permissible	60-90	50-80		60-90		50-80	60-90	50-80				
Daylight		50% Sunlight	55-70% Sunlight		50% Sunlight		55-70% Sunlight	50% Sunlight		55-70% Sunlight			
Supplemental light		None	8 watts/ft² incandescent or equivalent at least 3% of the time, no dark period over 30 min.	None		8 watts/ft² incandescent or equivalent at least 3% of the time, no dark period over 30 min		None	8 watts/ft² incandescent or equivalent at least 3% of the time, no dark period over 30 min.				
Water		Frequent, light, surface kept wet.	As needed, surface should dry Water in excess. Keep rootball near field cap.	As needed Dry to wilting	Frequent, light, surface kept wet.	As needed, surface should dry. Water in excess Keep rootball near field cap	Stress	Frequent, light, surface wet	As needed, surface should dry. Water in excess. Keep rootball near field capacity				
Fertilizer		None	Complete, high N, pH 5.0-5 5	Low N, high P	None	Complete, high N, pH 5 0-5.5		None	Complete, high N, pH 5.0-5.5				
CO_2 level		Normal atmos	1,000-1,500 ppm whenever vents are closed in daylight hours.	Normal atmos	Normal atmos.	1,000-1,500 ppm whenever vents are closed in daylight hours		Normal atmos	Normal atmos , CO_2 at higher levels not usually feasible because of venting needs				
Operations	Leach Crop #1	Thin Apply fungicide		Move to lathhouse. Load Crop #2	Thin Fungicide		Ship Crop #1 for outplanting	Move Crop #2 to lathhouse. Thin Fungicide	Ship Crop #2 for outplanting		Move Crop #3 to lathhouse. Temperatures usually too high for greenhouse production		
					Harden Crop #1 in lathhouse		Load Crop #3		Harden Crop #2 in lathhouse		Harden or ship for outplanting		

Species Douglas – fir **Container** 3-10 cubic inches **Outplanting** Fall/ Winter/Spring **Location** Corvallis, Oreg. **Cycle** Summer Info. Grade A, B

Source West Coast (Courtesy of Peyton W. Owston, Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg.)

Season	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
Growth stage	Sowing	Germination	Juvenile growth	Height			Natural hardening Bud set Caliper growth		Cold hardening		Maintain dormancy and hardiness		
Day temp (°F) Optimum		75-85	75-85	70-80			76-70	45-55	35-40		35-40		
Day temp (°F) Permissible		70-85	70-90	65-90			50-85	40-70	30-40		25-50		
Night temp (°F) Optimum		65-70	55-60	55-60			55-60	40-50	33-36		33-36		
Night temp (°F) Permissible		60-80	50-65	50-65			45-65	35-60	25-45		25-40		
Rel. Hum. (%) Optimum		65-80	50-70	50-70	Same								
Rel. Hum. (%) Permissible		55-90	40-80	40-80									
Daylight		50-75% Sunlight	65-80% Sunlight			100% Sunlight		50-100% Sunlight					
Supplemental light		None	None					None					
Water		Frequent light, surface always wet	As needed. Surface should dry, water in excess each time 5-6 bars tension is reached			Leach w/H_2O Dry to 22 bars PMS		As needed. Surface should dry, water in excess each time 0.5-3 bars tension is reached					
Fertilizer		None	Complete high N. pH 5.5-5.0. Rinse foliage			Leach w/H_2O Dry to 22 bars PMS		Complete, low N, high PK.					
CO_2 level		Normal atmosphere											
Operations	Fill, seed, load, ghs.		Thin to one per pot. Apply fungicide if needed.				NOTE: Trees in greenhouse all winter, or in shadehouse if minimum air temp. is usually above freezing. Brief periods down to 25° F are acceptable.				Perhaps move to cooler to prevent bud break anytime after Jan. 1.		

Outplant anytime site conditions are favorable.

Appendix 3

Probability tables for determining the proportion of containers expected to have a certain number of seedlings, giving the number of seeds sown and the germination percent (Balmer and Space 1976).

TABLE 1 2 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES
1	.98010	.01980	.00010
2	.96040	.03920	.00040
3	.94090	.05820	.00090
4	.92160	.07680	.00160
5	.90250	.09500	.00250
6	.88360	.11280	.00360
7	.86490	.13020	.00490
8	.84640	.14720	.00640
9	.82810	.16380	.00810
10	.81000	.18000	.01000
11	.79210	.19580	.01210
12	.77440	.21120	.01440
13	.75690	.22620	.01690
14	.73960	.24080	.01960
15	.72250	.25500	.02250
16	.70560	.26880	.02560
17	.68890	.28220	.02890
18	.67240	.29520	.03240
19	.65610	.30780	.03610
20	.64000	.32000	.04000
21	.62410	.33180	.04410
22	.60840	.34320	.04840
23	.59290	.35420	.05290
24	.57760	.36480	.05760
25	.56250	.37500	.06250
26	.54760	.38480	.06760
27	.53290	.39420	.07290
28	.51840	.40320	.07840
29	.50410	.41180	.08410
30	.49000	.42000	.09000
31	.47610	.42780	.09610
32	.46240	.43520	.10240
33	.44890	.44220	.10890
34	.43560	.44880	.11560
35	.42250	.45500	.12250
36	.40960	.46080	.12960
37	.39690	.46620	.13690
38	.38440	.47120	.14440
39	.37210	.47580	.15210
40	.36000	.48000	.16000
41	.34810	.48380	.16810
42	.33640	.48720	.17640
43	.32490	.49020	.18490
44	.31360	.49280	.19360
45	.30250	.49500	.20250
46	.29160	.49680	.21160
47	.28090	.49820	.22090
48	.27040	.49920	.23040
49	.26010	.49980	.24010
50	.25000	.50000	.25000

TABLE 1 2 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES
51	.24010	.49980	.26010
52	.23040	.49920	.27040
53	.22090	.49820	.28090
54	.21160	.49680	.29160
55	.20250	.49500	.30250
56	.19360	.49280	.31360
57	.18490	.49020	.32490
58	.17640	.48720	.33640
59	.16810	.48380	.34810
60	.16000	.48000	.36000
61	.15210	.47580	.37210
62	.14440	.47120	.38440
63	.13690	.46620	.39690
64	.12960	.46080	.40960
65	.12250	.45500	.42250
66	.11560	.44880	.43560
67	.10890	.44220	.44890
68	.10240	.43520	.46240
69	.09610	.42780	.47610
70	.09000	.42000	.49000
71	.08410	.41180	.50410
72	.07840	.40320	.51840
73	.07290	.39420	.53290
74	.06760	.38480	.54760
75	.06250	.37500	.56250
76	.05760	.36480	.57760
77	.05290	.35420	.59290
78	.04840	.34320	.60840
79	.04410	.33180	.62410
80	.04000	.32000	.64000
81	.03610	.30780	.65610
82	.03240	.29520	.67240
83	.02890	.28220	.68890
84	.02560	.26880	.70560
85	.02250	.25500	.72250
86	.01960	.24080	.73960
87	.01690	.22620	.75690
88	.01440	.21120	.77440
89	.01210	.19580	.79210
90	.01000	.18000	.81000
91	.00810	.16380	.82810
92	.00640	.14720	.84640
93	.00490	.13020	.86490
94	.00360	.11280	.88360
95	.00250	.09500	.90250
96	.00160	.07680	.92160
97	.00090	.05820	.94090
98	.00040	.03920	.96040
99	.00010	.01980	.98010

TABLE 2 3 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES
1	.97030	.02940	.00030	.00000
2	.94119	.05762	.00118	.00001
3	.91267	.08468	.00262	.00003
4	.88474	.11059	.00461	.00006
5	.85737	.13537	.00712	.00012
6	.83058	.15905	.01015	.00022
7	.80436	.18163	.01367	.00034
8	.77869	.20314	.01766	.00051
9	.75357	.22359	.02211	.00073
10	.72900	.24300	.02700	.00100
11	.70497	.26139	.03231	.00133
12	.68147	.27878	.03802	.00173
13	.65850	.29519	.04411	.00220
14	.63606	.31063	.05057	.00274
15	.61412	.32512	.05737	.00337
16	.59270	.33869	.06451	.00410
17	.57179	.35134	.07196	.00491
18	.55137	.36310	.07970	.00583
19	.53144	.37398	.08772	.00686
20	.51200	.38400	.09600	.00800
21	.49304	.39318	.10452	.00926
22	.47455	.40154	.11326	.01065
23	.45653	.40910	.12220	.01217
24	.43898	.41587	.13133	.01382
25	.42188	.42188	.14063	.01563
26	.40522	.42713	.15007	.01758
27	.38902	.43165	.15965	.01968
28	.37325	.43546	.16934	.02195
29	.35791	.43857	.17913	.02439
30	.34300	.44100	.18900	.02700
31	.32851	.44277	.19893	.02979
32	.31443	.44390	.20890	.03277
33	.30076	.44441	.21889	.03594
34	.28750	.44431	.22889	.03930
35	.27462	.44362	.23887	.04287
36	.26214	.44237	.24883	.04666
37	.25005	.44056	.25874	.05065
38	.23833	.43822	.26858	.05487
39	.22698	.43536	.27834	.05932
40	.21600	.43200	.28800	.06400
41	.20538	.42816	.29754	.06892
42	.19511	.42386	.30694	.07409
43	.18519	.41912	.31618	.07951
44	.17562	.41395	.32525	.08518
45	.16637	.40837	.33412	.09112
46	.15746	.40241	.34279	.09734
47	.14888	.39607	.35123	.10382
48	.14061	.38938	.35942	.11059
49	.13265	.38235	.36735	.11765
50	.12500	.37500	.37500	.12500

TABLE 2 3 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES
51	.11765	.36735	.38235	.13265
52	.11059	.35942	.38938	.14061
53	.10382	.35123	.39607	.14888
54	.09734	.34279	.40241	.15746
55	.09112	.33412	.40837	.16637
56	.08518	.32525	.41395	.17562
57	.07951	.31618	.41912	.18519
58	.07409	.30694	.42386	.19511
59	.06892	.29754	.42816	.20538
60	.06400	.28800	.43200	.21600
61	.05932	.27834	.43536	.22698
62	.05487	.26858	.43822	.23833
63	.05065	.25874	.44056	.25005
64	.04666	.24883	.44237	.26214
65	.04287	.23887	.44362	.27462
66	.03930	.22889	.44431	.28750
67	.03594	.21889	.44441	.30076
68	.03277	.20890	.44390	.31443
69	.02979	.19893	.44277	.32851
70	.02700	.18900	.44100	.34300
71	.02439	.17913	.43857	.35791
72	.02195	.16934	.43546	.37325
73	.01968	.15965	.43165	.38902
74	.01758	.15007	.42713	.40522
75	.01563	.14063	.42188	.42188
76	.01382	.13133	.41587	.43898
77	.01217	.12220	.40910	.45653
78	.01065	.11326	.40154	.47455
79	.00926	.10452	.39318	.49304
80	.00800	.09600	.38400	.51200
81	.00686	.08772	.37398	.53144
82	.00583	.07970	.36310	.55137
83	.00491	.07196	.35134	.57179
84	.00410	.06451	.33869	.59270
85	.00337	.05737	.32512	.61412
86	.00274	.05057	.31063	.63606
87	.00220	.04411	.29519	.65850
88	.00173	.03802	.27878	.68147
89	.00133	.03231	.26139	.70497
90	.00100	.02700	.24300	.72900
91	.00073	.02211	.22359	.75357
92	.00051	.01766	.20314	.77869
93	.00034	.01367	.18163	.80436
94	.00022	.01015	.15905	.83058
95	.00012	.00712	.13537	.85737
96	.00006	.00461	.11059	.88474
97	.00003	.00262	.08468	.91267
98	.00001	.00118	.05762	.94119
99	.00000	.00030	.02940	.97030

TABLE 3 4 SEEDS PER CONTAINER

GERMINATION PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES
	PROBABILITY OF OCCURANCE				
1	.96060	.03881	.00059	.00000	.00000
2	.92237	.07530	.00230	.00003	.00000
3	.88529	.10952	.00508	.00010	.00000
4	.84935	.14156	.00885	.00025	.00000
5	.81451	.17147	.01354	.00047	.00001
6	.78075	.19934	.01909	.00081	.00001
7	.74805	.22522	.02543	.00128	.00002
8	.71639	.24918	.03250	.00188	.00004
9	.68575	.27129	.04025	.00265	.00007
10	.65610	.29160	.04860	.00360	.00010
11	.62742	.31019	.05751	.00474	.00015
12	.59970	.32711	.06691	.00608	.00021
13	.57290	.34242	.07675	.00765	.00029
14	.54701	.35619	.08698	.00944	.00038
15	.52201	.36847	.09754	.01147	.00051
16	.49787	.37933	.10838	.01376	.00066
17	.47458	.38882	.11946	.01631	.00084
18	.45212	.39698	.13071	.01913	.00105
19	.43047	.40390	.14211	.02222	.00130
20	.40960	.40960	.15360	.02560	.00160
21	.38950	.41415	.16514	.02926	.00194
22	.37015	.41761	.17668	.03322	.00234
23	.35153	.42001	.18819	.03747	.00280
24	.33362	.42142	.19962	.04202	.00332
25	.31641	.42188	.21094	.04688	.00391
26	.29987	.42143	.22211	.05202	.00457
27	.28398	.42014	.23309	.05747	.00531
28	.26874	.41804	.24386	.06322	.00615
29	.25412	.41518	.25437	.06926	.00707
30	.24010	.41160	.26460	.07560	.00810
31	.22667	.40735	.27452	.08222	.00924
32	.21381	.40247	.28410	.08913	.01049
33	.20151	.39701	.29331	.09631	.01186
34	.18975	.39099	.30213	.10376	.01336
35	.17851	.38447	.31054	.11147	.01501
36	.16777	.37749	.31850	.11944	.01680
37	.15753	.37007	.32601	.12765	.01874
38	.14776	.36226	.33304	.13608	.02085
39	.13846	.35409	.33958	.14474	.02313
40	.12960	.34560	.34560	.15360	.02560
41	.12117	.33682	.35109	.16265	.02826
42	.11316	.32779	.35605	.17188	.03112
43	.10556	.31853	.36044	.18128	.03419
44	.09834	.30908	.36428	.19081	.03748
45	.09151	.29947	.36754	.20047	.04101
46	.08503	.28973	.37022	.21025	.04477
47	.07890	.27989	.37230	.22010	.04880
48	.07312	.26997	.37380	.23003	.05308
49	.06765	.26000	.37470	.24000	.05765
50	.06250	.25000	.37500	.25000	.06250

TABLE 3 4 SEEDS PER CONTAINER

GERMINATION PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES
	PROBABILITY OF OCCURANCE				
51	.05765	.24000	.37470	.26000	.06765
52	.05308	.23003	.37380	.26997	.07312
53	.04880	.22010	.37230	.27989	.07890
54	.04477	.21025	.37022	.28973	.08503
55	.04101	.20047	.36754	.29947	.09151
56	.03748	.19081	.36428	.30908	.09834
57	.03419	.18128	.36044	.31853	.10556
58	.03112	.17188	.35605	.32779	.11316
59	.02826	.16265	.35109	.33682	.12117
60	.02560	.15360	.34560	.34560	.12960
61	.02313	.14474	.33958	.35409	.13846
62	.02085	.13608	.33304	.36226	.14776
63	.01874	.12765	.32601	.37007	.15753
64	.01680	.11944	.31850	.37749	.16777
65	.01501	.11147	.31054	.38447	.17851
66	.01336	.10376	.30213	.39099	.18975
67	.01186	.09631	.29331	.39701	.20151
68	.01049	.08913	.28410	.40247	.21381
69	.00924	.08222	.27452	.40735	.22667
70	.00810	.07560	.26460	.41160	.24010
71	.00707	.06926	.25437	.41518	.25412
72	.00615	.06322	.24386	.41804	.26874
73	.00531	.05747	.23309	.42014	.28398
74	.00457	.05202	.22211	.42143	.29987
75	.00391	.04688	.21094	.42188	.31641
76	.00332	.04202	.19962	.42142	.33362
77	.00280	.03747	.18819	.42001	.35153
78	.00234	.03322	.17668	.41761	.37015
79	.00194	.02926	.16514	.41415	.38950
80	.00160	.02560	.15360	.40960	.40960
81	.00130	.02222	.14211	.40390	.43047
82	.00105	.01913	.13071	.39698	.45212
83	.00084	.01631	.11946	.38882	.47458
84	.00066	.01376	.10838	.37933	.49787
85	.00051	.01147	.09754	.36847	.52201
86	.00038	.00944	.08698	.35619	.54701
87	.00029	.00765	.07675	.34242	.57290
88	.00021	.00608	.06691	.32711	.59970
89	.00015	.00474	.05751	.31019	.62742
90	.00010	.00360	.04860	.29160	.65610
91	.00007	.00265	.04025	.27129	.68575
92	.00004	.00188	.03250	.24918	.71639
93	.00002	.00128	.02543	.22522	.74805
94	.00001	.00081	.01909	.19934	.78075
95	.00001	.00047	.01354	.17147	.81451
96	.00000	.00025	.00885	.14156	.84935
97	.00000	.00010	.00508	.10952	.88529
98	.00000	.00003	.00230	.07530	.92237
99	.00000	.00000	.00059	.03881	.96060

TABLE 4 5 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES
1	.95099	.04803	.00097	.00001	.00000	.00000
2	.90392	.09224	.00376	.00008	.00000	.00000
3	.85873	.13279	.00821	.00025	.00000	.00000
4	.81537	.16987	.01416	.00059	.00001	.00000
5	.77378	.20363	.02143	.00113	.00003	.00000
6	.73390	.23422	.02990	.00191	.00006	.00000
7	.69569	.26182	.03941	.00297	.00011	.00000
8	.65908	.28656	.04984	.00433	.00019	.00000
9	.62403	.30859	.06104	.00604	.00030	.00001
10	.59049	.32805	.07290	.00810	.00045	.00001
11	.55841	.34508	.08530	.01054	.00065	.00002
12	.52773	.35982	.09813	.01338	.00091	.00002
13	.49842	.37238	.11129	.01663	.00124	.00004
14	.47043	.38291	.12467	.02029	.00165	.00005
15	.44371	.39150	.13818	.02438	.00215	.00008
16	.41821	.39830	.15173	.02890	.00275	.00010
17	.39390	.40340	.16525	.03385	.00347	.00014
18	.37074	.40691	.17864	.03921	.00430	.00019
19	.34868	.40894	.19185	.04500	.00528	.00025
20	.32768	.40960	.20480	.05120	.00640	.00032
21	.30771	.40898	.21743	.05780	.00768	.00041
22	.28872	.40717	.22968	.06478	.00914	.00052
23	.27068	.40426	.24151	.07214	.01077	.00064
24	.25355	.40035	.25285	.07985	.01261	.00080
25	.23730	.39551	.26367	.08789	.01465	.00098
26	.22190	.38983	.27393	.09625	.01691	.00119
27	.20731	.38338	.28359	.10489	.01940	.00143
28	.19349	.37623	.29263	.11380	.02213	.00172
29	.18042	.36847	.30100	.12294	.02511	.00205
30	.16807	.36015	.30870	.13230	.02835	.00243
31	.15640	.35134	.31570	.14183	.03186	.00286
32	.14539	.34210	.32198	.15152	.03565	.00336
33	.13501	.33249	.32753	.16132	.03973	.00391
34	.12523	.32257	.33235	.17121	.04410	.00454
35	.11603	.31239	.33642	.18115	.04877	.00525
36	.10737	.30199	.33974	.19110	.05375	.00605
37	.09924	.29143	.34231	.20104	.05904	.00693
38	.09161	.28075	.34415	.21093	.06464	.00792
39	.08446	.26999	.34524	.22073	.07056	.00902
40	.07776	.25920	.34560	.23040	.07680	.01024
41	.07149	.24841	.34524	.23991	.08336	.01159
42	.06564	.23765	.34418	.24923	.09024	.01307
43	.06017	.22695	.34242	.25832	.09744	.01470
44	.05507	.21636	.33999	.26714	.10495	.01649
45	.05033	.20589	.33691	.27565	.11277	.01845
46	.04592	.19557	.33319	.28383	.12089	.02060
47	.04182	.18543	.32887	.29164	.12931	.02293
48	.03802	.17548	.32396	.29904	.13802	.02548
49	.03450	.16575	.31850	.30601	.14700	.02825
50	.03125	.15625	.31250	.31250	.15625	.03125

TABLE 4 5 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES
51	.02825	.14700	.30601	.31850	.16575	.03450
52	.02548	.13802	.29904	.32396	.17548	.03802
53	.02293	.12931	.29164	.32887	.18543	.04182
54	.02060	.12089	.28383	.33319	.19557	.04592
55	.01845	.11277	.27565	.33691	.20589	.05033
56	.01649	.10495	.26714	.33999	.21636	.05507
57	.01470	.09744	.25832	.34242	.22695	.06017
58	.01307	.09024	.24923	.34418	.23765	.06564
59	.01159	.08336	.23991	.34524	.24841	.07149
60	.01024	.07680	.23040	.34560	.25920	.07776
61	.00902	.07056	.22073	.34524	.26999	.08446
62	.00792	.06464	.21093	.34415	.28075	.09161
63	.00693	.05904	.20104	.34231	.29143	.09924
64	.00605	.05375	.19110	.33974	.30199	.10737
65	.00525	.04877	.18115	.33642	.31239	.11603
66	.00454	.04410	.17121	.33235	.32257	.12523
67	.00391	.03973	.16132	.32753	.33249	.13501
68	.00336	.03565	.15152	.32198	.34210	.14539
69	.00286	.03186	.14183	.31570	.35134	.15640
70	.00243	.02835	.13230	.30870	.36015	.16807
71	.00205	.02511	.12294	.30100	.36847	.18042
72	.00172	.02213	.11380	.29263	.37623	.19349
73	.00143	.01940	.10489	.28359	.38338	.20731
74	.00119	.01691	.09625	.27393	.38983	.22190
75	.00098	.01465	.08789	.26367	.39551	.23730
76	.00080	.01261	.07985	.25285	.40035	.25355
77	.00064	.01077	.07214	.24151	.40426	.27068
78	.00052	.00914	.06478	.22968	.40717	.28872
79	.00041	.00768	.05780	.21743	.40898	.30771
80	.00032	.00640	.05120	.20480	.40960	.32768
81	.00025	.00528	.04500	.19185	.40894	.34868
82	.00019	.00430	.03921	.17864	.40691	.37074
83	.00014	.00347	.03385	.16525	.40340	.39390
84	.00010	.00275	.02890	.15173	.39830	.41821
85	.00008	.00215	.02438	.13818	.39150	.44371
86	.00005	.00165	.02029	.12467	.38291	.47043
87	.00004	.00124	.01663	.11129	.37238	.49842
88	.00002	.00091	.01338	.09813	.35982	.52773
89	.00002	.00065	.01054	.08530	.34508	.55841
90	.00001	.00045	.00810	.07290	.32805	.59049
91	.00001	.00030	.00604	.06104	.30859	.62403
92	.00000	.00019	.00433	.04984	.28656	.65908
93	.00000	.00011	.00297	.03941	.26182	.69569
94	.00000	.00006	.00191	.02990	.23422	.73390
95	.00000	.00003	.00113	.02143	.20363	.77378
96	.00000	.00001	.00059	.01416	.16987	.81537
97	.00000	.00000	.00025	.00821	.13279	.85873
98	.00000	.00000	.00008	.00376	.09224	.90392
99	.00000	.00000	.00001	.00097	.04803	.95099

TABLE 5 6 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES
1	.94148	.05706	.00144	.00002	.00000	.00000	.00000
2	.88584	.10847	.00553	.00015	.00000	.00000	.00000
3	.83297	.15457	.01195	.00049	.00001	.00000	.00000
4	.78276	.19569	.02038	.00113	.00004	.00000	.00000
5	.73509	.23213	.03054	.00214	.00008	.00000	.00000
6	.68987	.26421	.04216	.00359	.00017	.00000	.00000
7	.64699	.29219	.05498	.00552	.00031	.00001	.00000
8	.60635	.31636	.06877	.00797	.00052	.00002	.00000
9	.56787	.33698	.08332	.01099	.00081	.00003	.00000
10	.53144	.35429	.09841	.01458	.00121	.00005	.00000
11	.49698	.36855	.11388	.01877	.00174	.00009	.00000
12	.46440	.37997	.12953	.02355	.00241	.00013	.00000
13	.43363	.38877	.14523	.02893	.00324	.00019	.00000
14	.40457	.39516	.16082	.03491	.00426	.00028	.00001
15	.37715	.39933	.17618	.04145	.00549	.00039	.00001
16	.35130	.40148	.19118	.04855	.00694	.00053	.00002
17	.32694	.40178	.20573	.05618	.00863	.00071	.00002
18	.30401	.40040	.21973	.06431	.01059	.00093	.00003
19	.28243	.39749	.23310	.07290	.01283	.00120	.00005
20	.26214	.39322	.24576	.08192	.01536	.00154	.00006
21	.24309	.38771	.25765	.09132	.01821	.00194	.00009
22	.22520	.38111	.26873	.10106	.02138	.00241	.00011
23	.20842	.37354	.27894	.11109	.02489	.00297	.00015
24	.19270	.36512	.28825	.12137	.02875	.00363	.00019
25	.17798	.35596	.29663	.13184	.03296	.00439	.00024
26	.16421	.34617	.30406	.14244	.03754	.00528	.00031
27	.15133	.33584	.31053	.15314	.04248	.00628	.00039
28	.13931	.32507	.31604	.16387	.04780	.00743	.00048
29	.12810	.31394	.32057	.17458	.05348	.00874	.00059
30	.11765	.30253	.32413	.18522	.05953	.01021	.00073
31	.10792	.29091	.32675	.19573	.06595	.01185	.00089
32	.09887	.27916	.32842	.20607	.07273	.01369	.00107
33	.09046	.26732	.32917	.21617	.07985	.01573	.00129
34	.08265	.25548	.32902	.22599	.08732	.01799	.00154
35	.07542	.24366	.32801	.23549	.09510	.02048	.00184
36	.06872	.23193	.32615	.24461	.10320	.02322	.00218
37	.06252	.22032	.32349	.25331	.11158	.02621	.00257
38	.05680	.20888	.32006	.26155	.12023	.02948	.00301
39	.05152	.19764	.31589	.26929	.12912	.03302	.00352
40	.04666	.18662	.31104	.27648	.13824	.03686	.00410
41	.04218	.17587	.30554	.28310	.14755	.04101	.00475
42	.03807	.16540	.29943	.28911	.15702	.04548	.00549
43	.03430	.15524	.29277	.29448	.16662	.05028	.00632
44	.03084	.14539	.28559	.29919	.17631	.05541	.00726
45	.02768	.13589	.27795	.30322	.18607	.06089	.00830
46	.02479	.12673	.26989	.30654	.19584	.06673	.00947
47	.02216	.11793	.26145	.30914	.20561	.07293	.01078
48	.01977	.10950	.25269	.31100	.21531	.07950	.01223
49	.01760	.10144	.24365	.31213	.22491	.08644	.01384
50	.01563	.09375	.23438	.31250	.23438	.09375	.01563

TABLE 5 6 SEEDS PER CONTAINER

GERMINATION	PROBABILITY OF OCCURANCE						
PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES
51	.01384	.08644	.22491	.31213	.24365	.10144	.01760
52	.01223	.07950	.21531	.31100	.25269	.10950	.01977
53	.01078	.07293	.20561	.30914	.26145	.11793	.02216
54	.00947	.06673	.19584	.30654	.26989	.12673	.02479
55	.00830	.06089	.18607	.30322	.27795	.13589	.02768
56	.00726	.05541	.17631	.29919	.28559	.14539	.03084
57	.00632	.05028	.16662	.29448	.29277	.15524	.03430
58	.00549	.04548	.15702	.28911	.29943	.16540	.03807
59	.00475	.04101	.14755	.28310	.30554	.17587	.04218
60	.00410	.03686	.13824	.27648	.31104	.18662	.04666
61	.00352	.03302	.12912	.26929	.31589	.19764	.05152
62	.00301	.02948	.12023	.26155	.32006	.20888	.05680
63	.00257	.02621	.11158	.25331	.32349	.22032	.06252
64	.00218	.02322	.10320	.24461	.32615	.23193	.06872
65	.00184	.02048	.09510	.23549	.32801	.24366	.07542
66	.00154	.01799	.08732	.22599	.32902	.25548	.08265
67	.00129	.01573	.07985	.21617	.32917	.26732	.09046
68	.00107	.01369	.07273	.20607	.32842	.27916	.09887
69	.00089	.01185	.06595	.19573	.32675	.29091	.10792
70	.00073	.01021	.05953	.18522	.32413	.30253	.11765
71	.00059	.00874	.05348	.17458	.32057	.31394	.12810
72	.00048	.00743	.04780	.16387	.31604	.32507	.13931
73	.00039	.00628	.04248	.15314	.31053	.33584	.15133
74	.00031	.00528	.03754	.14244	.30406	.34617	.16421
75	.00024	.00439	.03296	.13184	.29663	.35596	.17798
76	.00019	.00363	.02875	.12137	.28825	.36512	.19270
77	.00015	.00297	.02489	.11109	.27894	.37354	.20842
78	.00011	.00241	.02138	.10106	.26873	.38111	.22520
79	.00009	.00194	.01821	.09132	.25765	.38771	.24309
80	.00006	.00154	.01536	.08192	.24576	.39322	.26214
81	.00005	.00120	.01283	.07290	.23310	.39749	.28243
82	.00003	.00093	.01059	.06431	.21973	.40040	.30401
83	.00002	.00071	.00863	.05618	.20573	.40178	.32694
84	.00002	.00053	.00694	.04855	.19118	.40148	.35130
85	.00001	.00039	.00549	.04145	.17618	.39933	.37715
86	.00001	.00028	.00426	.03491	.16082	.39516	.40457
87	.00000	.00019	.00324	.02893	.14523	.38877	.43363
88	.00000	.00013	.00241	.02355	.12953	.37997	.46440
89	.00000	.00009	.00174	.01877	.11388	.36855	.49698
90	.00000	.00005	.00121	.01458	.09841	.35429	.53144
91	.00000	.00003	.00081	.01099	.08332	.33698	.56787
92	.00000	.00002	.00052	.00797	.06877	.31636	.60635
93	.00000	.00001	.00031	.00552	.05498	.29219	.64699
94	.00000	.00000	.00017	.00359	.04216	.26421	.68987
95	.00000	.00000	.00008	.00214	.03054	.23213	.73509
96	.00000	.00000	.00004	.00113	.02038	.19569	.78276
97	.00000	.00000	.00001	.00049	.01195	.15457	.83297
98	.00000	.00000	.00000	.00015	.00553	.10847	.88584
99	.00000	.00000	.00000	.00002	.00144	.05706	.94148

TABLE 6 7 SEEDS PER CONTAINER

GERMINATION	PROBABILITY OF OCCURANCE							
PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES
1	.93207	.06590	.00200	.00003	.00000	.00000	.00000	.00000
2	.86813	.12402	.00759	.00026	.00001	.00000	.00000	.00000
3	.80798	.17492	.01623	.00084	.00003	.00000	.00000	.00000
4	.75145	.21917	.02740	.00190	.00008	.00000	.00000	.00000
5	.69834	.25728	.04062	.00356	.00019	.00001	.00000	.00000
6	.64848	.28975	.05548	.00590	.00038	.00001	.00000	.00000
7	.60170	.31703	.07159	.00898	.00068	.00003	.00000	.00000
8	.55785	.33956	.08858	.01284	.00112	.00006	.00000	.00000
9	.51676	.35776	.10615	.01750	.00173	.00010	.00000	.00000
10	.47830	.37201	.12400	.02296	.00255	.00017	.00001	.00000
11	.44231	.38268	.14189	.02923	.00361	.00027	.00001	.00000
12	.40868	.39010	.15959	.03627	.00495	.00040	.00002	.00000
13	.37725	.39460	.17689	.04405	.00658	.00059	.00003	.00000
14	.34793	.39648	.19363	.05253	.00855	.00084	.00005	.00000
15	.32058	.39601	.20965	.06166	.01088	.00115	.00007	.00000
16	.29509	.39345	.22483	.07137	.01360	.00155	.00010	.00000
17	.27136	.38906	.23906	.08161	.01671	.00205	.00014	.00000
18	.24929	.38305	.25225	.09229	.02026	.00267	.00020	.00001
19	.22877	.37563	.26433	.10334	.02424	.00341	.00027	.00001
20	.20972	.36700	.27525	.11469	.02867	.00430	.00036	.00001
21	.19204	.35734	.28497	.12625	.03356	.00535	.00047	.00002
22	.17566	.34681	.29345	.13795	.03891	.00658	.00062	.00002
23	.16049	.33556	.30070	.14970	.04471	.00801	.00080	.00003
24	.14645	.32374	.30670	.16142	.05097	.00966	.00102	.00005
25	.13348	.31146	.31146	.17303	.05768	.01154	.00128	.00006
26	.12151	.29886	.31501	.18447	.06481	.01366	.00160	.00008
27	.11047	.28602	.31737	.19564	.07236	.01606	.00198	.00010
28	.10031	.27306	.31856	.20648	.08030	.01874	.00243	.00013
29	.09095	.26004	.31864	.21692	.08860	.02171	.00296	.00017
30	.08235	.24706	.31765	.22689	.09724	.02500	.00357	.00022
31	.07446	.23418	.31564	.23635	.10618	.02862	.00429	.00028
32	.06723	.22146	.31265	.24522	.11540	.03258	.00511	.00034
33	.06061	.20896	.30876	.25346	.12484	.03689	.00606	.00043
34	.05455	.19672	.30402	.26102	.13447	.04156	.00714	.00053
35	.04902	.18478	.29848	.26787	.14424	.04660	.00836	.00064
36	.04398	.17317	.29223	.27397	.15411	.05201	.00975	.00078
37	.03939	.16194	.28532	.27928	.16402	.05780	.01131	.00095
38	.03522	.15109	.27781	.28378	.17393	.06396	.01307	.00114
39	.03143	.14065	.26977	.28746	.18379	.07050	.01503	.00137
40	.02799	.13064	.26127	.29030	.19354	.07741	.01720	.00164
41	.02489	.12106	.25238	.29230	.20312	.08469	.01962	.00195
42	.02208	.11192	.24314	.29345	.21250	.09233	.02229	.00231
43	.01955	.10323	.23363	.29375	.22160	.10030	.02522	.00272
44	.01727	.09499	.22391	.29321	.23038	.10861	.02844	.00319
45	.01522	.08719	.21402	.29185	.23878	.11722	.03197	.00374
46	.01339	.07984	.20403	.28968	.24676	.12612	.03581	.00436
47	.01175	.07292	.19400	.28672	.25427	.13529	.03999	.00507
48	.01028	.06643	.18396	.28301	.26124	.14469	.04452	.00587
49	.00897	.06036	.17397	.27857	.26765	.15429	.04941	.00678
50	.00781	.05469	.16406	.27344	.27344	.16406	.05469	.00781

TABLE 6 7 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES
51	.00678	.04941	.15429	.26765	.27857	.17397	.06036	.00897
52	.00587	.04452	.14469	.26124	.28301	.18396	.06643	.01028
53	.00507	.03999	.13529	.25427	.28672	.19400	.07292	.01175
54	.00436	.03581	.12612	.24676	.28968	.20403	.07984	.01339
55	.00374	.03197	.11722	.23878	.29185	.21402	.08719	.01522
56	.00319	.02844	.10861	.23038	.29321	.22391	.09499	.01727
57	.00272	.02522	.10030	.22160	.29375	.23363	.10323	.01955
58	.00231	.02229	.09233	.21250	.29345	.24314	.11192	.02208
59	.00195	.01962	.08469	.20312	.29230	.25238	.12106	.02489
60	.00164	.01720	.07741	.19354	.29030	.26127	.13064	.02799
61	.00137	.01503	.07050	.18379	.28746	.26977	.14065	.03143
62	.00114	.01307	.06396	.17393	.28378	.27781	.15109	.03522
63	.00095	.01131	.05780	.16402	.27928	.28532	.16194	.03939
64	.00078	.00975	.05201	.15411	.27397	.29223	.17317	.04398
65	.00064	.00836	.04660	.14424	.26787	.29848	.18478	.04902
66	.00053	.00714	.04156	.13447	.26102	.30402	.19672	.05455
67	.00043	.00606	.03689	.12484	.25346	.30876	.20896	.06061
68	.00034	.00511	.03258	.11540	.24522	.31265	.22146	.06723
69	.00028	.00429	.02862	.10618	.23635	.31564	.23418	.07446
70	.00022	.00357	.02500	.09724	.22689	.31765	.24706	.08235
71	.00017	.00296	.02171	.08860	.21692	.31864	.26004	.09095
72	.00013	.00243	.01874	.08030	.20648	.31856	.27306	.10031
73	.00010	.00198	.01606	.07236	.19564	.31737	.28602	.11047
74	.00008	.00160	.01366	.06481	.18447	.31501	.29886	.12151
75	.00006	.00128	.01154	.05768	.17303	.31146	.31146	.13348
76	.00005	.00102	.00966	.05097	.16142	.30670	.32374	.14645
77	.00003	.00080	.00801	.04471	.14970	.30070	.33556	.16049
78	.00002	.00062	.00658	.03891	.13795	.29345	.34681	.17566
79	.00002	.00047	.00535	.03356	.12625	.28497	.35734	.19204
80	.00001	.00036	.00430	.02867	.11469	.27525	.36700	.20972
81	.00001	.00027	.00341	.02424	.10334	.26433	.37563	.22877
82	.00001	.00020	.00267	.02026	.09229	.25225	.38305	.24929
83	.00000	.00014	.00205	.01671	.08161	.23906	.38906	.27136
84	.00000	.00010	.00155	.01360	.07137	.22483	.39345	.29509
85	.00000	.00007	.00115	.01088	.06166	.20965	.39601	.32058
86	.00000	.00005	.00084	.00855	.05253	.19363	.39648	.34793
87	.00000	.00003	.00059	.00658	.04405	.17689	.39460	.37725
88	.00000	.00002	.00040	.00495	.03627	.15959	.39010	.40868
89	.00000	.00001	.00027	.00361	.02923	.14189	.38268	.44231
90	.00000	.00001	.00017	.00255	.02296	.12400	.37201	.47830
91	.00000	.00000	.00010	.00173	.01750	.10615	.35776	.51676
92	.00000	.00000	.00006	.00112	.01284	.08858	.33956	.55785
93	.00000	.00000	.00003	.00068	.00898	.07159	.31703	.60170
94	.00000	.00000	.00001	.00038	.00590	.05548	.28975	.64848
95	.00000	.00000	.00001	.00019	.00356	.04062	.25728	.69834
96	.00000	.00000	.00000	.00008	.00190	.02740	.21917	.75145
97	.00000	.00000	.00000	.00003	.00084	.01623	.17492	.80798
98	.00000	.00000	.00000	.00001	.00026	.00759	.12402	.86813
99	.00000	.00000	.00000	.00000	.00003	.00200	.06590	.93207

TABLE 7 8 SEEDS PER CONTAINER

GERMINATION	PROBABILITY OF OCCURANCE								
PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES
1	.92274	.07457	.00264	.00005	.00000	.00000	.00000	.00000	.00000
2	.85076	.13890	.00992	.00040	.00001	.00000	.00000	.00000	.00000
3	.78374	.19392	.02099	.00130	.00005	.00000	.00000	.00000	.00000
4	.72139	.24046	.03507	.00292	.00015	.00001	.00000	.00000	.00000
5	.66342	.27933	.05146	.00542	.00036	.00002	.00000	.00000	.00000
6	.60957	.31127	.06954	.00888	.00071	.00004	.00000	.00000	.00000
7	.55958	.33695	.08877	.01336	.00126	.00008	.00000	.00000	.00000
8	.51322	.35702	.10866	.01890	.00205	.00014	.00001	.00000	.00000
9	.47025	.37207	.12879	.02548	.00315	.00025	.00001	.00000	.00000
10	.43047	.38264	.14880	.03307	.00459	.00041	.00002	.00000	.00000
11	.39366	.38924	.16838	.04162	.00643	.00064	.00004	.00000	.00000
12	.35963	.39233	.18725	.05107	.00870	.00095	.00006	.00000	.00000
13	.32821	.39234	.20519	.06132	.01145	.00137	.00010	.00000	.00000
14	.29922	.38968	.22203	.07229	.01471	.00192	.00016	.00001	.00000
15	.27249	.38469	.23760	.08386	.01850	.00261	.00023	.00001	.00000
16	.24788	.37772	.25181	.09593	.02284	.00348	.00033	.00002	.00000
17	.22523	.36905	.26456	.10837	.02775	.00455	.00047	.00003	.00000
18	.20441	.35897	.27579	.12108	.03322	.00583	.00064	.00004	.00000
19	.18530	.34773	.28548	.13393	.03927	.00737	.00086	.00006	.00000
20	.16777	.33554	.29360	.14680	.04588	.00918	.00115	.00008	.00000
21	.15171	.32263	.30016	.15958	.05303	.01128	.00150	.00011	.00000
22	.13701	.30915	.30519	.17216	.06070	.01370	.00193	.00016	.00001
23	.12357	.29529	.30872	.18443	.06886	.01646	.00246	.00021	.00001
24	.11130	.28119	.31079	.19629	.07748	.01957	.00309	.00028	.00001
25	.10011	.26697	.31146	.20764	.08652	.02307	.00385	.00037	.00002
26	.08992	.25275	.31081	.21841	.09592	.02696	.00474	.00048	.00002
27	.08065	.23862	.30890	.22850	.10564	.03126	.00578	.00061	.00003
28	.07222	.22469	.30582	.23786	.11563	.03597	.00699	.00078	.00004
29	.06458	.21101	.30165	.24642	.12581	.04111	.00840	.00098	.00005
30	.05765	.19765	.29648	.25412	.13614	.04668	.01000	.00122	.00007
31	.05138	.18467	.29039	.26093	.14653	.05267	.01183	.00152	.00009
32	.04572	.17211	.28347	.26680	.15694	.05908	.01390	.00187	.00011
33	.04061	.16000	.27583	.27171	.16728	.06591	.01623	.00228	.00014
34	.03600	.14838	.26753	.27564	.17750	.07315	.01884	.00277	.00018
35	.03186	.13726	.25869	.27859	.18751	.08077	.02175	.00335	.00023
36	.02815	.12666	.24937	.28054	.19725	.08876	.02497	.00401	.00028
37	.02482	.11659	.23967	.28151	.20667	.09710	.02851	.00478	.00035
38	.02183	.10706	.22965	.28151	.21567	.10575	.03241	.00568	.00043
39	.01917	.09805	.21941	.28056	.22422	.11468	.03666	.00670	.00054
40	.01680	.08958	.20902	.27869	.23224	.12386	.04129	.00786	.00066
41	.01468	.08163	.19854	.27593	.23969	.13325	.04630	.00919	.00080
42	.01281	.07419	.18803	.27232	.24649	.14280	.05170	.01070	.00097
43	.01114	.06725	.17756	.26790	.25262	.15246	.05751	.01239	.00117
44	.00967	.06079	.16718	.26272	.25802	.16219	.06372	.01430	.00140
45	.00837	.05481	.15695	.25683	.26266	.17192	.07033	.01644	.00168
46	.00723	.04927	.14690	.25028	.26650	.18162	.07736	.01883	.00200
47	.00623	.04417	.13709	.24314	.26952	.19121	.08478	.02148	.00238
48	.00535	.03948	.12754	.23547	.27169	.20063	.09260	.02442	.00282
49	.00458	.03518	.11830	.22731	.27300	.20984	.10080	.02767	.00332
50	.00391	.03125	.10938	.21875	.27344	.21875	.10938	.03125	.00391

TABLE 7 8 SEEDS PER CONTAINER

GERMINATION		PROBABILITY OF OCCURANCE							
PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES
51	.00332	.02767	.10080	.20984	.27300	.22731	.11830	.03518	.00458
52	.00282	.02442	.09260	.20063	.27169	.23547	.12754	.03948	.00535
53	.00238	.02148	.08478	.19121	.26952	.24314	.13709	.04417	.00623
54	.00200	.01883	.07736	.18162	.26650	.25028	.14690	.04927	.00723
55	.00168	.01644	.07033	.17192	.26266	.25683	.15695	.05481	.00837
56	.00140	.01430	.06372	.16219	.25802	.26272	.16718	.06079	.00967
57	.00117	.01239	.05751	.15246	.25262	.26790	.17756	.06725	.01114
58	.00097	.01070	.05170	.14280	.24649	.27232	.18803	.07419	.01281
59	.00080	.00919	.04630	.13325	.23969	.27593	.19854	.08163	.01468
60	.00066	.00786	.04129	.12386	.23224	.27869	.20902	.08958	.01680
61	.00054	.00670	.03666	.11468	.22422	.28056	.21941	.09805	.01917
62	.00043	.00568	.03241	.10575	.21567	.28151	.22965	.10706	.02183
63	.00035	.00478	.02851	.09710	.20667	.28151	.23967	.11659	.02482
64	.00028	.00401	.02497	.08876	.19725	.28054	.24937	.12666	.02815
65	.00023	.00335	.02175	.08077	.18751	.27859	.25869	.13726	.03186
66	.00018	.00277	.01884	.07315	.17750	.27564	.26753	.14838	.03600
67	.00014	.00228	.01623	.06591	.16728	.27171	.27583	.16000	.04061
68	.00011	.00187	.01390	.05908	.15694	.26680	.28347	.17211	.04572
69	.00009	.00152	.01183	.05267	.14653	.26093	.29039	.18467	.05138
70	.00007	.00122	.01000	.04668	.13614	.25412	.29648	.19765	.05765
71	.00005	.00098	.00840	.04111	.12581	.24642	.30165	.21101	.06458
72	.00004	.00078	.00699	.03597	.11563	.23786	.30582	.22469	.07222
73	.00003	.00061	.00578	.03126	.10564	.22850	.30890	.23862	.08065
74	.00002	.00048	.00474	.02696	.09592	.21841	.31081	.25275	.08992
75	.00002	.00037	.00385	.02307	.08652	.20764	.31146	.26697	.10011
76	.00001	.00028	.00309	.01957	.07748	.19629	.31079	.28119	.11130
77	.00001	.00021	.00246	.01646	.06886	.18443	.30872	.29529	.12357
78	.00001	.00016	.00193	.01370	.06070	.17216	.30519	.30915	.13701
79	.00000	.00011	.00150	.01128	.05303	.15958	.30016	.32263	.15171
80	.00000	.00008	.00115	.00918	.04588	.14680	.29360	.33554	.16777
81	.00000	.00006	.00086	.00737	.03927	.13393	.28548	.34773	.18530
82	.00000	.00004	.00064	.00583	.03322	.12108	.27579	.35897	.20441
83	.00000	.00003	.00047	.00455	.02775	.10837	.26456	.36905	.22523
84	.00000	.00002	.00033	.00348	.02284	.09593	.25181	.37772	.24788
85	.00000	.00001	.00023	.00261	.01850	.08386	.23760	.38469	.27249
86	.00000	.00001	.00016	.00192	.01471	.07229	.22203	.38968	.29922
87	.00000	.00000	.00010	.00137	.01145	.06132	.20519	.39234	.32821
88	.00000	.00000	.00006	.00095	.00870	.05107	.18725	.39233	.35963
89	.00000	.00000	.00004	.00064	.00643	.04162	.16838	.38924	.39366
90	.00000	.00000	.00002	.00041	.00459	.03307	.14880	.38264	.43047
91	.00000	.00000	.00001	.00025	.00315	.02548	.12879	.37207	.47025
92	.00000	.00000	.00001	.00014	.00205	.01890	.10866	.35702	.51322
93	.00000	.00000	.00000	.00008	.00126	.01336	.08877	.33695	.55958
94	.00000	.00000	.00000	.00004	.00071	.00888	.06954	.31127	.60957
95	.00000	.00000	.00000	.00002	.00036	.00542	.05146	.27933	.66342
96	.00000	.00000	.00000	.00001	.00015	.00292	.03507	.24046	.72139
97	.00000	.00000	.00000	.00000	.00005	.00130	.02099	.19392	.78374
98	.00000	.00000	.00000	.00000	.00001	.00040	.00992	.13890	.85076
99	.00000	.00000	.00000	.00000	.00000	.00005	.00264	.07457	.92274

TABLE 9 9 SEEDS PER CONTAINER

GERMINATION	PROBABILITY OF OCCURANCE									
PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES
1	.91352	.08305	.00336	.00008	.00000	.00000	.00000	.00000	.00000	.00000
2	.83375	.15314	.01250	.00060	.00002	.00000	.00000	.00000	.00000	.00000
3	.76023	.21161	.02618	.00189	.00009	.00000	.00000	.00000	.00000	.00000
4	.69253	.25970	.04328	.00421	.00026	.00001	.00000	.00000	.00000	.00000
5	.63025	.29854	.06285	.00772	.00061	.00003	.00000	.00000	.00000	.00000
6	.57299	.32917	.08404	.01252	.00120	.00008	.00000	.00000	.00000	.00000
7	.52041	.35254	.10614	.01864	.00210	.00016	.00001	.00000	.00000	.00000
8	.47216	.36952	.12853	.02608	.00340	.00030	.00002	.00000	.00000	.00000
9	.42793	.38090	.15069	.03477	.00516	.00051	.00003	.00000	.00000	.00000
10	.38742	.38742	.17219	.04464	.00744	.00083	.00006	.00000	.00000	.00000
11	.35036	.38972	.19267	.05556	.01030	.00127	.00010	.00001	.00000	.00000
12	.31648	.38841	.21186	.06741	.01379	.00188	.00017	.00001	.00000	.00000
13	.28554	.38401	.22952	.08002	.01794	.00268	.00027	.00002	.00000	.00000
14	.25733	.37701	.24550	.09325	.02277	.00371	.00040	.00003	.00000	.00000
15	.23162	.36786	.25967	.10692	.02830	.00499	.00059	.00004	.00000	.00000
16	.20822	.35694	.27196	.12087	.03453	.00658	.00084	.00007	.00000	.00000
17	.18694	.34460	.28232	.13493	.04145	.00849	.00116	.00010	.00001	.00000
18	.16762	.33115	.29077	.14893	.04904	.01076	.00158	.00015	.00001	.00000
19	.15009	.31687	.29731	.16272	.05725	.01343	.00210	.00021	.00001	.00000
20	.13422	.30199	.30199	.17616	.06606	.01652	.00275	.00029	.00002	.00000
21	.11985	.28673	.30488	.18910	.07540	.02004	.00355	.00040	.00003	.00000
22	.10687	.27128	.30606	.20143	.08522	.02404	.00452	.00055	.00004	.00000
23	.09515	.25580	.30563	.21301	.09544	.02851	.00568	.00073	.00005	.00000
24	.08459	.24042	.30368	.22377	.10599	.03347	.00705	.00095	.00008	.00000
25	.07508	.22525	.30034	.23360	.11680	.03893	.00865	.00124	.00010	.00000
26	.06654	.21041	.29571	.24243	.12777	.04489	.01052	.00158	.00014	.00001
27	.05887	.19597	.28993	.25021	.13882	.05134	.01266	.00201	.00019	.00001
28	.05200	.18200	.28310	.25689	.14985	.05828	.01511	.00252	.00024	.00001
29	.04585	.16854	.27536	.26244	.16079	.06567	.01788	.00313	.00032	.00001
30	.04035	.15565	.26683	.26683	.17153	.07351	.02100	.00386	.00041	.00002
31	.03545	.14335	.25761	.27006	.18200	.08177	.02449	.00472	.00053	.00003
32	.03109	.13166	.24784	.27213	.19209	.09040	.02836	.00572	.00067	.00004
33	.02721	.12060	.23760	.27307	.20174	.09937	.03263	.00689	.00085	.00005
34	.02376	.11017	.22702	.27288	.21087	.10863	.03731	.00824	.00106	.00006
35	.02071	.10037	.21619	.27162	.21939	.11813	.04241	.00979	.00132	.00008
36	.01801	.09120	.20520	.26932	.22724	.12782	.04793	.01156	.00162	.00010
37	.01563	.08264	.19413	.26603	.23436	.13764	.05389	.01356	.00199	.00013
38	.01354	.07467	.18307	.26181	.24069	.14752	.06028	.01583	.00243	.00017
39	.01169	.06729	.17208	.25672	.24619	.15740	.06709	.01838	.00294	.00021
40	.01008	.06047	.16124	.25082	.25082	.16722	.07432	.02123	.00354	.00026
41	.00866	.05418	.15060	.24420	.25455	.17689	.08195	.02441	.00424	.00033
42	.00743	.04841	.14022	.23692	.25734	.18635	.08996	.02792	.00505	.00041
43	.00635	.04312	.13013	.22905	.25919	.19553	.09834	.03179	.00600	.00050
44	.00542	.03830	.12037	.22068	.26009	.20436	.10704	.03605	.00708	.00062
45	.00461	.03391	.11099	.21188	.26004	.21276	.11605	.04069	.00832	.00076
46	.00390	.02993	.10199	.20273	.25904	.22067	.12532	.04575	.00974	.00092
47	.00330	.02634	.09342	.19330	.25712	.22801	.13480	.05123	.01136	.00112
48	.00278	.02309	.08527	.18366	.25430	.23474	.14446	.05715	.01319	.00135
49	.00233	.02018	.07757	.17390	.25061	.24079	.15423	.06351	.01525	.00163
50	.00195	.01758	.07031	.16406	.24609	.24609	.16406	.07031	.01758	.00195

TABLE 8 9 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES
51	.00163	.01525	.06351	.15423	.24079	.25061	.17390	.07757	.02018	.00233
52	.00135	.01319	.05715	.14446	.23474	.25430	.18366	.08527	.02309	.00278
53	.00112	.01136	.05123	.13480	.22801	.25712	.19330	.09342	.02634	.00330
54	.00092	.00974	.04575	.12532	.22067	.25904	.20273	.10199	.02993	.00390
55	.00076	.00832	.04069	.11605	.21276	.26004	.21188	.11099	.03391	.00461
56	.00062	.00708	.03605	.10704	.20436	.26009	.22068	.12037	.03830	.00542
57	.00050	.00600	.03179	.09834	.19553	.25919	.22905	.13013	.04312	.00635
58	.00041	.00505	.02792	.08996	.18635	.25734	.23692	.14022	.04841	.00743
59	.00033	.00424	.02441	.08195	.17689	.25455	.24420	.15060	.05418	.00866
60	.00026	.00354	.02123	.07432	.16722	.25082	.25082	.16124	.06047	.01008
61	.00021	.00294	.01838	.06709	.15740	.24619	.25672	.17208	.06729	.01169
62	.00017	.00243	.01583	.06028	.14752	.24069	.26181	.18307	.07467	.01354
63	.00013	.00199	.01356	.05389	.13764	.23436	.26603	.19413	.08264	.01563
64	.00010	.00162	.01156	.04793	.12782	.22724	.26932	.20520	.09120	.01801
65	.00008	.00132	.00979	.04241	.11813	.21939	.27162	.21619	.10037	.02071
66	.00006	.00106	.00824	.03731	.10863	.21087	.27288	.22702	.11017	.02376
67	.00005	.00085	.00689	.03263	.09937	.20174	.27307	.23760	.12060	.02721
68	.00004	.00067	.00572	.02836	.09040	.19209	.27213	.24784	.13166	.03109
69	.00003	.00053	.00472	.02449	.08177	.18200	.27006	.25761	.14335	.03545
70	.00002	.00041	.00386	.02100	.07351	.17153	.26683	.26683	.15565	.04035
71	.00001	.00032	.00313	.01788	.06567	.16079	.26244	.27536	.16854	.04585
72	.00001	.00024	.00252	.01511	.05828	.14985	.25689	.28310	.18200	.05200
73	.00001	.00019	.00201	.01266	.05134	.13882	.25021	.28993	.19597	.05887
74	.00001	.00014	.00158	.01052	.04489	.12777	.24243	.29571	.21041	.06654
75	.00000	.00010	.00124	.00865	.03893	.11680	.23360	.30034	.22525	.07508
76	.00000	.00008	.00095	.00705	.03347	.10599	.22377	.30368	.24042	.08459
77	.00000	.00005	.00073	.00568	.02851	.09544	.21301	.30563	.25580	.09515
78	.00000	.00004	.00055	.00452	.02404	.08522	.20143	.30606	.27128	.10687
79	.00000	.00003	.00040	.00355	.02004	.07540	.18910	.30488	.28673	.11985
80	.00000	.00002	.00029	.00275	.01652	.06606	.17616	.30199	.30199	.13422
81	.00000	.00001	.00021	.00210	.01343	.05725	.16272	.29731	.31687	.15009
82	.00000	.00001	.00015	.00158	.01076	.04904	.14893	.29077	.33115	.16762
83	.00000	.00001	.00010	.00116	.00849	.04145	.13493	.28232	.34460	.18694
84	.00000	.00000	.00007	.00084	.00658	.03453	.12087	.27196	.35694	.20822
85	.00000	.00000	.00004	.00059	.00499	.02830	.10692	.25967	.36786	.23162
86	.00000	.00000	.00003	.00040	.00371	.02277	.09325	.24550	.37701	.25733
87	.00000	.00000	.00002	.00027	.00268	.01794	.08002	.22952	.38401	.28554
88	.00000	.00000	.00001	.00017	.00188	.01379	.06741	.21186	.38841	.31648
89	.00000	.00000	.00001	.00010	.00127	.01030	.05556	.19267	.38972	.35036
90	.00000	.00000	.00000	.00006	.00083	.00744	.04464	.17219	.38742	.38742
91	.00000	.00000	.00000	.00003	.00051	.00516	.03477	.15069	.38090	.42793
92	.00000	.00000	.00000	.00002	.00030	.00340	.02608	.12853	.36952	.47216
93	.00000	.00000	.00000	.00001	.00016	.00210	.01864	.10614	.35254	.52041
94	.00000	.00000	.00000	.00000	.00008	.00120	.01252	.08404	.32917	.57299
95	.00000	.00000	.00000	.00000	.00003	.00061	.00772	.06285	.29854	.63025
96	.00000	.00000	.00000	.00000	.00001	.00026	.00421	.04328	.25970	.69253
97	.00000	.00000	.00000	.00000	.00000	.00009	.00189	.02618	.21161	.76023
98	.00000	.00000	.00000	.00000	.00000	.00002	.00060	.01250	.15314	.83375
99	.00000	.00000	.00000	.00000	.00000	.00000	.00008	.00336	.08305	.91352

TABLE 9 10 SEEDS PER CONTAINER

GERMINATION	PROBABILITY OF OCCURANCE										
PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES	10 TREES
1	.90438	.09135	.00415	.00011	.00000	.00000	.00000	.00000	.00000	.00000	.00000
2	.81707	.16675	.01531	.00083	.00003	.00000	.00000	.00000	.00000	.00000	.00000
3	.73742	.22807	.03174	.00262	.00014	.00001	.00000	.00000	.00000	.00000	.00000
4	.66483	.27701	.05194	.00577	.00042	.00002	.00000	.00000	.00000	.00000	.00000
5	.59874	.31512	.07463	.01048	.00096	.00006	.00000	.00000	.00000	.00000	.00000
6	.53862	.34380	.09875	.01681	.00188	.00014	.00001	.00000	.00000	.00000	.00000
7	.48398	.36429	.12339	.02477	.00326	.00029	.00002	.00000	.00000	.00000	.00000
8	.43439	.37773	.14781	.03427	.00522	.00054	.00004	.00000	.00000	.00000	.00000
9	.38942	.38514	.17141	.04521	.00782	.00093	.00008	.00000	.00000	.00000	.00000
10	.34868	.38742	.19371	.05740	.01116	.00149	.00014	.00001	.00000	.00000	.00000
11	.31182	.38539	.21435	.07065	.01528	.00227	.00023	.00002	.00000	.00000	.00000
12	.27850	.37977	.23304	.08474	.02022	.00331	.00038	.00003	.00000	.00000	.00000
13	.24842	.37121	.24960	.09946	.02601	.00466	.00058	.00005	.00000	.00000	.00000
14	.22130	.36026	.26391	.11457	.03264	.00638	.00086	.00008	.00000	.00000	.00000
15	.19687	.34743	.27590	.12983	.04010	.00849	.00125	.00013	.00001	.00000	.00000
16	.17490	.33315	.28555	.14504	.04835	.01105	.00175	.00019	.00001	.00000	.00000
17	.15516	.31780	.29291	.15998	.05734	.01409	.00241	.00028	.00002	.00000	.00000
18	.13745	.30172	.29804	.17446	.06702	.01765	.00323	.00041	.00003	.00000	.00000
19	.12158	.28518	.30102	.18829	.07729	.02176	.00425	.00057	.00005	.00000	.00000
20	.10737	.26844	.30199	.20133	.08808	.02642	.00551	.00079	.00007	.00000	.00000
21	.09468	.25169	.30107	.21342	.09928	.03167	.00702	.00107	.00011	.00001	.00000
22	.08336	.23511	.29841	.22445	.11078	.03750	.00881	.00142	.00015	.00001	.00000
23	.07327	.21885	.29417	.23431	.12248	.04390	.01093	.00187	.00021	.00001	.00000
24	.06429	.20302	.28850	.24295	.13426	.05088	.01339	.00242	.00029	.00002	.00000
25	.05631	.18771	.28157	.25028	.14600	.05840	.01622	.00309	.00039	.00003	.00000
26	.04924	.17301	.27354	.25629	.15758	.06644	.01945	.00391	.00051	.00004	.00000
27	.04298	.15895	.26456	.26094	.16889	.07496	.02310	.00488	.00068	.00006	.00000
28	.03744	.14560	.25479	.26423	.17982	.08392	.02720	.00604	.00088	.00008	.00000
29	.03255	.13296	.24439	.26619	.19027	.09326	.03174	.00741	.00113	.00010	.00000
30	.02825	.12106	.23347	.26683	.20012	.10292	.03676	.00900	.00145	.00014	.00001
31	.02446	.10990	.22219	.26620	.20930	.11284	.04225	.01085	.00183	.00018	.00001
32	.02114	.09948	.21066	.26436	.21771	.12294	.04821	.01296	.00229	.00024	.00001
33	.01823	.08978	.19899	.26136	.22528	.13315	.05465	.01538	.00284	.00031	.00002
34	.01568	.08079	.18729	.25729	.23195	.14339	.06156	.01812	.00350	.00040	.00002
35	.01346	.07249	.17565	.25222	.23767	.15357	.06891	.02120	.00428	.00051	.00003
36	.01153	.06485	.16416	.24623	.24239	.16361	.07669	.02465	.00520	.00065	.00004
37	.00985	.05785	.15288	.23943	.24608	.17343	.08488	.02848	.00627	.00082	.00005
38	.00839	.05144	.14188	.23189	.24872	.18293	.09343	.03272	.00752	.00102	.00006
39	.00713	.04561	.13121	.22371	.25030	.19203	.10231	.03738	.00896	.00127	.00008
40	.00605	.04031	.12093	.21499	.25082	.20066	.11148	.04247	.01062	.00157	.00010
41	.00511	.03552	.11107	.20582	.25030	.20873	.12087	.04800	.01251	.00193	.00013
42	.00431	.03120	.10166	.19630	.24876	.21617	.13044	.05398	.01466	.00236	.00017
43	.00362	.02731	.09271	.18651	.24623	.22290	.14013	.06041	.01709	.00286	.00022
44	.00303	.02383	.08426	.17655	.24275	.22888	.14986	.06728	.01982	.00346	.00027
45	.00253	.02072	.07630	.16648	.23837	.23403	.15957	.07460	.02289	.00416	.00034
46	.00211	.01796	.06885	.15639	.23314	.23832	.16918	.08235	.02631	.00498	.00042
47	.00175	.01551	.06189	.14635	.22713	.24170	.17861	.09051	.03010	.00593	.00053
48	.00145	.01334	.05543	.13644	.22040	.24413	.18779	.09906	.03429	.00703	.00065
49	.00119	.01144	.04945	.12670	.21302	.24560	.19664	.10796	.03890	.00830	.00080
50	.00098	.00977	.04395	.11719	.20508	.24609	.20508	.11719	.04395	.00977	.00098

TABLE 9 10 SEEDS PER CONTAINER

GERMINATION	PROBABILITY OF OCCURANCE										
PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES	10 TREES
51	.00080	.00830	.03890	.10796	.19664	.24560	.21302	.12670	.04945	.01144	.00119
52	.00065	.00703	.03429	.09906	.18779	.24413	.22040	.13644	.05543	.01334	.00145
53	.00053	.00593	.03010	.09051	.17861	.24170	.22713	.14635	.06189	.01551	.00175
54	.00042	.00498	.02631	.08235	.16918	.23832	.23314	.15639	.06885	.01796	.00211
55	.00034	.00416	.02289	.07460	.15957	.23403	.23837	.16648	.07630	.02072	.00253
56	.00027	.00346	.01982	.06728	.14986	.22888	.24275	.17655	.08426	.02383	.00303
57	.00022	.00286	.01709	.06041	.14013	.22290	.24623	.18651	.09271	.02731	.00362
58	.00017	.00236	.01466	.05398	.13044	.21617	.24876	.19630	.10166	.03120	.00431
59	.00013	.00193	.01251	.04800	.12087	.20873	.25030	.20582	.11107	.03552	.00511
60	.00010	.00157	.01062	.04247	.11148	.20066	.25082	.21499	.12093	.04031	.00605
61	.00008	.00127	.00896	.03738	.10231	.19203	.25030	.22371	.13121	.04561	.00713
62	.00006	.00102	.00752	.03272	.09343	.18293	.24872	.23189	.14188	.05144	.00839
63	.00005	.00082	.00627	.02848	.08488	.17343	.24608	.23943	.15288	.05785	.00985
64	.00004	.00065	.00520	.02465	.07669	.16361	.24239	.24623	.16416	.06485	.01153
65	.00003	.00051	.00428	.02120	.06891	.15357	.23767	.25222	.17565	.07249	.01346
66	.00002	.00040	.00350	.01812	.06156	.14339	.23195	.25729	.18729	.08079	.01568
67	.00002	.00031	.00284	.01538	.05465	.13315	.22528	.26136	.19899	.08978	.01823
68	.00001	.00024	.00229	.01296	.04821	.12294	.21771	.26436	.21066	.09948	.02114
69	.00001	.00018	.00183	.01085	.04225	.11284	.20930	.26620	.22219	.10990	.02446
70	.00001	.00014	.00145	.00900	.03676	.10292	.20012	.26683	.23347	.12106	.02825
71	.00000	.00010	.00113	.00741	.03174	.09326	.19027	.26619	.24439	.13296	.03255
72	.00000	.00008	.00088	.00604	.02720	.08392	.17982	.26423	.25479	.14560	.03744
73	.00000	.00006	.00068	.00488	.02310	.07496	.16889	.26094	.26456	.15895	.04298
74	.00000	.00004	.00051	.00391	.01945	.06644	.15758	.25629	.27354	.17301	.04924
75	.00000	.00003	.00039	.00309	.01622	.05840	.14600	.25028	.28157	.18771	.05631
76	.00000	.00002	.00029	.00242	.01339	.05088	.13426	.24295	.28850	.20302	.06429
77	.00000	.00001	.00021	.00187	.01093	.04390	.12248	.23431	.29417	.21885	.07327
78	.00000	.00001	.00015	.00142	.00881	.03750	.11078	.22445	.29841	.23511	.08336
79	.00000	.00001	.00011	.00107	.00702	.03167	.09928	.21342	.30107	.25169	.09468
80	.00000	.00000	.00007	.00079	.00551	.02642	.08808	.20133	.30199	.26844	.10737
81	.00000	.00000	.00005	.00057	.00425	.02176	.07729	.18829	.30102	.28518	.12158
82	.00000	.00000	.00003	.00041	.00323	.01765	.06702	.17446	.29804	.30172	.13745
83	.00000	.00000	.00002	.00028	.00241	.01409	.05734	.15998	.29291	.31780	.15516
84	.00000	.00000	.00001	.00019	.00175	.01105	.04835	.14504	.28555	.33315	.17490
85	.00000	.00000	.00001	.00013	.00125	.00849	.04010	.12983	.27590	.34743	.19687
86	.00000	.00000	.00000	.00008	.00086	.00638	.03264	.11457	.26391	.36026	.22130
87	.00000	.00000	.00000	.00005	.00058	.00466	.02601	.09946	.24960	.37121	.24842
88	.00000	.00000	.00000	.00003	.00038	.00331	.02022	.08474	.23304	.37977	.27850
89	.00000	.00000	.00000	.00002	.00023	.00227	.01528	.07065	.21435	.38539	.31182
90	.00000	.00000	.00000	.00001	.00014	.00149	.01116	.05740	.19371	.38742	.34868
91	.00000	.00000	.00000	.00000	.00008	.00093	.00782	.04521	.17141	.38514	.38942
92	.00000	.00000	.00000	.00000	.00004	.00054	.00522	.03427	.14781	.37773	.43439
93	.00000	.00000	.00000	.00000	.00002	.00029	.00326	.02477	.12339	.36429	.48398
94	.00000	.00000	.00000	.00000	.00001	.00014	.00188	.01681	.09875	.34380	.53862
95	.00000	.00000	.00000	.00000	.00000	.00006	.00096	.01048	.07463	.31512	.59874
96	.00000	.00000	.00000	.00000	.00000	.00002	.00042	.00577	.05194	.27701	.66483
97	.00000	.00000	.00000	.00000	.00000	.00001	.00014	.00262	.03174	.22807	.73742
98	.00000	.00000	.00000	.00000	.00000	.00000	.00003	.00083	.01531	.16675	.81707
99	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00011	.00415	.09135	.90438

TABLE 10 11 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES	10 TREES	11 TREES
1	.89534	.09948	.00502	.00015	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
2	.80073	.17976	.01834	.00112	.00005	.00000	.00000	.00000	.00000	.00000	.00000	.00000
3	.71530	.24335	.03763	.00349	.00022	.00001	.00000	.00000	.00000	.00000	.00000	.00000
4	.63824	.29253	.06094	.00762	.00063	.00004	.00000	.00000	.00000	.00000	.00000	.00000
5	.56880	.32931	.08666	.01368	.00144	.00011	.00001	.00000	.00000	.00000	.00000	.00000
6	.50630	.35549	.11345	.02173	.00277	.00025	.00002	.00000	.00000	.00000	.00000	.00000
7	.45010	.37267	.14025	.03167	.00477	.00050	.00004	.00000	.00000	.00000	.00000	.00000
8	.39964	.38226	.16620	.04336	.00754	.00092	.00008	.00000	.00000	.00000	.00000	.00000
9	.35437	.38552	.19064	.05656	.01119	.00155	.00015	.00001	.00000	.00000	.00000	.00000
10	.31381	.38355	.21308	.07103	.01578	.00246	.00027	.00002	.00000	.00000	.00000	.00000
11	.27752	.37730	.23316	.08645	.02137	.00370	.00046	.00004	.00000	.00000	.00000	.00000
12	.24508	.36762	.25065	.10254	.02797	.00534	.00073	.00007	.00000	.00000	.00000	.00000
13	.21613	.35525	.26541	.11898	.03556	.00744	.00111	.00012	.00001	.00000	.00000	.00000
14	.19032	.34080	.27740	.13547	.04411	.01005	.00164	.00019	.00002	.00000	.00000	.00000
15	.16734	.32484	.28663	.15174	.05356	.01323	.00233	.00029	.00003	.00000	.00000	.00000
16	.14692	.30783	.29317	.16752	.06382	.01702	.00324	.00044	.00004	.00000	.00000	.00000
17	.12878	.29015	.29714	.18258	.07479	.02145	.00439	.00064	.00007	.00000	.00000	.00000
18	.11271	.27215	.29870	.19670	.08636	.02654	.00583	.00091	.00010	.00001	.00000	.00000
19	.09848	.25410	.29801	.20971	.09838	.03231	.00758	.00127	.00015	.00001	.00000	.00000
20	.08590	.23622	.29528	.22146	.11073	.03876	.00969	.00173	.00022	.00002	.00000	.00000
21	.07480	.21872	.29070	.23182	.12325	.04587	.01219	.00232	.00031	.00003	.00000	.00000
22	.06502	.20173	.28449	.24072	.13579	.05362	.01512	.00305	.00043	.00004	.00000	.00000
23	.05642	.18537	.27684	.24808	.14820	.06198	.01851	.00395	.00059	.00006	.00000	.00000
24	.04886	.16972	.26798	.25388	.16034	.07089	.02239	.00505	.00080	.00008	.00001	.00000
25	.04224	.15486	.25810	.25810	.17207	.08030	.02677	.00637	.00106	.00012	.00001	.00000
26	.03644	.14083	.24740	.26077	.18324	.09014	.03167	.00795	.00140	.00016	.00001	.00000
27	.03137	.12764	.23605	.26191	.19374	.10032	.03711	.00980	.00181	.00022	.00002	.00000
28	.02696	.11531	.22422	.26159	.20346	.11077	.04308	.01197	.00233	.00030	.00002	.00000
29	.02311	.10384	.21207	.25986	.21228	.12139	.04958	.01447	.00295	.00040	.00003	.00000
30	.01977	.09322	.19975	.25682	.22013	.13208	.05661	.01733	.00371	.00053	.00005	.00000
31	.01688	.08342	.18738	.25256	.22694	.14274	.06413	.02058	.00462	.00069	.00006	.00000
32	.01437	.07441	.17508	.24718	.23264	.15327	.07213	.02424	.00570	.00089	.00008	.00000
33	.01221	.06617	.16295	.24078	.23719	.16355	.08056	.02834	.00698	.00115	.00011	.00001
34	.01035	.05866	.15108	.23349	.24057	.17350	.08938	.03289	.00847	.00145	.00015	.00001
35	.00875	.05183	.13955	.22542	.24276	.18300	.09854	.03790	.01020	.00183	.00020	.00001
36	.00738	.04566	.12841	.21669	.24377	.19197	.10798	.04339	.01220	.00229	.00026	.00001
37	.00621	.04009	.11771	.20740	.24362	.20031	.11764	.04935	.01449	.00284	.00033	.00002
38	.00520	.03508	.10751	.19768	.24232	.20793	.12744	.05579	.01710	.00349	.00043	.00002
39	.00435	.03060	.09783	.18764	.23993	.21476	.13730	.06270	.02004	.00427	.00055	.00003
40	.00363	.02661	.08868	.17737	.23649	.22072	.14715	.07007	.02336	.00519	.00069	.00004
41	.00302	.02305	.08009	.16698	.23207	.22577	.15689	.07788	.02706	.00627	.00087	.00006
42	.00250	.01990	.07206	.15655	.22673	.22986	.16645	.08609	.03117	.00752	.00109	.00007
43	.00206	.01712	.06459	.14618	.22055	.23293	.17572	.09469	.03572	.00898	.00136	.00009
44	.00170	.01468	.05767	.13594	.21362	.23498	.18463	.10362	.04071	.01066	.00168	.00012
45	.00139	.01254	.05129	.12590	.20602	.23598	.19308	.11284	.04616	.01259	.00206	.00015
46	.00114	.01067	.04544	.11612	.19783	.23594	.20098	.12229	.05209	.01479	.00252	.00020
47	.00093	.00904	.04009	.10666	.18916	.23485	.20826	.13192	.05849	.01729	.00307	.00025
48	.00075	.00763	.03523	.09755	.18010	.23274	.21484	.14165	.06538	.02012	.00371	.00031
49	.00061	.00642	.03082	.08885	.17072	.22964	.22063	.15141	.07274	.02330	.00448	.00039
50	.00049	.00537	.02686	.08057	.16113	.22559	.22559	.16113	.08057	.02686	.00537	.00049

TABLE 10 11 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES	10 TREES	11 TREES
51	.00039	.00448	.02330	.07274	.15141	.22063	.22964	.17072	.08885	.03082	.00642	.00061
52	.00031	.00371	.02012	.06538	.14165	.21484	.23274	.18010	.09755	.03523	.00763	.00075
53	.00025	.00307	.01729	.05849	.13192	.20826	.23485	.18916	.10666	.04009	.00904	.00093
54	.00020	.00252	.01479	.05209	.12229	.20098	.23594	.19783	.11612	.04544	.01067	.00114
55	.00015	.00206	.01259	.04616	.11284	.19308	.23598	.20602	.12590	.05129	.01254	.00139
56	.00012	.00168	.01066	.04071	.10362	.18463	.23498	.21362	.13594	.05767	.01468	.00170
57	.00009	.00136	.00898	.03572	.09469	.17572	.23293	.22055	.14618	.06459	.01712	.00206
58	.00007	.00109	.00752	.03117	.08609	.16645	.22986	.22673	.15655	.07206	.01990	.00250
59	.00006	.00087	.00627	.02706	.07788	.15689	.22577	.23207	.16698	.08009	.02305	.00302
60	.00004	.00069	.00519	.02336	.07007	.14715	.22072	.23649	.17737	.08868	.02661	.00363
61	.00003	.00055	.00427	.02004	.06270	.13730	.21476	.23993	.18764	.09783	.03060	.00435
62	.00002	.00043	.00349	.01710	.05579	.12744	.20793	.24232	.19768	.10751	.03508	.00520
63	.00002	.00033	.00284	.01449	.04935	.11764	.20031	.24362	.20740	.11771	.04009	.00621
64	.00001	.00026	.00229	.01220	.04339	.10798	.19197	.24377	.21669	.12841	.04566	.00738
65	.00001	.00020	.00183	.01020	.03790	.09854	.18300	.24276	.22542	.13955	.05183	.00875
66	.00001	.00015	.00145	.00847	.03289	.08938	.17350	.24057	.23349	.15108	.05866	.01035
67	.00001	.00011	.00115	.00698	.02834	.08056	.16355	.23719	.24078	.16295	.06617	.01221
68	.00000	.00008	.00089	.00570	.02424	.07213	.15327	.23264	.24718	.17508	.07441	.01437
69	.00000	.00006	.00069	.00462	.02058	.06413	.14274	.22694	.25256	.18738	.08342	.01688
70	.00000	.00005	.00053	.00371	.01733	.05661	.13208	.22013	.25682	.19975	.09322	.01977
71	.00000	.00003	.00040	.00295	.01447	.04958	.12139	.21228	.25986	.21207	.10384	.02311
72	.00000	.00002	.00030	.00233	.01197	.04308	.11077	.20346	.26159	.22422	.11531	.02696
73	.00000	.00002	.00022	.00181	.00980	.03711	.10032	.19374	.26191	.23605	.12764	.03137
74	.00000	.00001	.00016	.00140	.00795	.03167	.09014	.18324	.26077	.24740	.14083	.03644
75	.00000	.00001	.00012	.00106	.00637	.02677	.08030	.17207	.25810	.25810	.15486	.04224
76	.00000	.00001	.00008	.00080	.00505	.02239	.07089	.16034	.25388	.26798	.16972	.04886
77	.00000	.00000	.00006	.00059	.00395	.01851	.06198	.14820	.24808	.27684	.18537	.05642
78	.00000	.00000	.00004	.00043	.00305	.01512	.05362	.13579	.24072	.28449	.20173	.06502
79	.00000	.00000	.00003	.00031	.00232	.01219	.04587	.12325	.23182	.29070	.21872	.07480
80	.00000	.00000	.00002	.00022	.00173	.00969	.03876	.11073	.22146	.29528	.23622	.08590
81	.00000	.00000	.00001	.00015	.00127	.00758	.03231	.09838	.20971	.29801	.25410	.09848
82	.00000	.00000	.00001	.00010	.00091	.00583	.02654	.08636	.19670	.29870	.27215	.11271
83	.00000	.00000	.00000	.00007	.00064	.00439	.02145	.07479	.18258	.29714	.29015	.12878
84	.00000	.00000	.00000	.00004	.00044	.00324	.01702	.06382	.16752	.29317	.30783	.14692
85	.00000	.00000	.00000	.00003	.00029	.00233	.01323	.05356	.15174	.28663	.32484	.16734
86	.00000	.00000	.00000	.00002	.00019	.00164	.01005	.04411	.13547	.27740	.34080	.19032
87	.00000	.00000	.00000	.00001	.00012	.00111	.00744	.03556	.11898	.26541	.35525	.21613
88	.00000	.00000	.00000	.00000	.00007	.00073	.00534	.02797	.10254	.25065	.36762	.24508
89	.00000	.00000	.00000	.00000	.00004	.00046	.00370	.02137	.08645	.23316	.37730	.27752
90	.00000	.00000	.00000	.00000	.00002	.00027	.00246	.01578	.07103	.21308	.38355	.31381
91	.00000	.00000	.00000	.00000	.00001	.00015	.00155	.01119	.05656	.19064	.38552	.35437
92	.00000	.00000	.00000	.00000	.00000	.00008	.00092	.00754	.04336	.16620	.38226	.39964
93	.00000	.00000	.00000	.00000	.00000	.00004	.00050	.00477	.03167	.14025	.37267	.45010
94	.00000	.00000	.00000	.00000	.00000	.00002	.00025	.00277	.02173	.11345	.35549	.50630
95	.00000	.00000	.00000	.00000	.00000	.00001	.00011	.00144	.01368	.08666	.32931	.56880
96	.00000	.00000	.00000	.00000	.00000	.00000	.00004	.00063	.00762	.06094	.29253	.63824
97	.00000	.00000	.00000	.00000	.00000	.00000	.00001	.00022	.00349	.03763	.24335	.71530
98	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00005	.00112	.01834	.17976	.80073
99	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00015	.00502	.09948	.89534

TABLE 11 12 SEEDS PER CONTAINER

GERMINATION	PROBABILITY OF OCCURANCE												
PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES	10 TREES	11 TREES	12 TREES
1	.88638	.10744	.00597	.00020	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
2	.78472	.19218	.02157	.00147	.00007	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
3	.69384	.25751	.04380	.00452	.00031	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000
4	.61271	.30635	.07021	.00975	.00091	.00006	.00000	.00000	.00000	.00000	.00000	.00000	.00000
5	.54036	.34128	.09879	.01733	.00205	.00017	.00001	.00000	.00000	.00000	.00000	.00000	.00000
6	.47592	.36453	.12797	.02723	.00391	.00040	.00003	.00000	.00000	.00000	.00000	.00000	.00000
7	.41860	.37809	.15652	.03927	.00665	.00080	.00007	.00000	.00000	.00000	.00000	.00000	.00000
8	.36767	.38365	.18349	.05318	.01041	.00145	.00015	.00001	.00000	.00000	.00000	.00000	.00000
9	.32248	.38272	.20818	.06863	.01527	.00242	.00028	.00002	.00000	.00000	.00000	.00000	.00000
10	.28243	.37657	.23013	.08523	.02131	.00379	.00049	.00005	.00000	.00000	.00000	.00000	.00000
11	.24699	.36632	.24902	.10259	.02853	.00564	.00081	.00009	.00001	.00000	.00000	.00000	.00000
12	.21567	.35292	.26469	.12031	.03691	.00805	.00128	.00015	.00001	.00000	.00000	.00000	.00000
13	.18803	.33716	.27709	.13801	.04640	.01109	.00193	.00025	.00002	.00000	.00000	.00000	.00000
14	.16367	.31974	.28628	.15534	.05690	.01482	.00281	.00039	.00004	.00000	.00000	.00000	.00000
15	.14224	.30122	.29236	.17198	.06828	.01928	.00397	.00060	.00007	.00001	.00000	.00000	.00000
16	.12341	.28208	.29551	.18763	.08041	.02451	.00545	.00089	.00011	.00001	.00000	.00000	.00000
17	.10689	.26272	.29595	.20206	.09312	.03052	.00729	.00128	.00016	.00001	.00000	.00000	.00000
18	.09242	.24345	.29392	.21506	.10622	.03731	.00955	.00180	.00025	.00002	.00000	.00000	.00000
19	.07977	.22453	.28967	.22649	.11954	.04486	.01228	.00247	.00036	.00004	.00000	.00000	.00000
20	.06872	.20616	.28347	.23622	.13288	.05315	.01550	.00332	.00052	.00006	.00000	.00000	.00000
21	.05909	.18849	.27558	.24419	.14605	.06212	.01926	.00439	.00073	.00009	.00001	.00000	.00000
22	.05071	.17165	.26628	.25035	.15887	.07170	.02359	.00570	.00101	.00013	.00001	.00000	.00000
23	.04344	.15571	.25580	.25470	.17118	.08181	.02851	.00730	.00136	.00018	.00002	.00000	.00000
24	.03713	.14072	.24440	.25726	.18279	.09236	.03403	.00921	.00182	.00026	.00002	.00000	.00000
25	.03168	.12671	.23229	.25810	.19358	.10324	.04015	.01147	.00239	.00035	.00004	.00000	.00000
26	.02696	.11369	.21969	.25729	.20340	.11434	.04687	.01412	.00310	.00048	.00005	.00000	.00000
27	.02290	.10165	.20678	.25493	.21215	.12555	.05417	.01717	.00397	.00065	.00007	.00000	.00000
28	.01941	.09057	.19372	.25112	.21973	.13672	.06203	.02068	.00503	.00087	.00010	.00001	.00000
29	.01641	.08043	.18069	.24600	.22608	.14775	.07041	.02465	.00629	.00114	.00014	.00001	.00000
30	.01384	.07118	.16779	.23970	.23114	.15850	.07925	.02911	.00780	.00149	.00019	.00001	.00000
31	.01165	.06279	.15515	.23235	.23488	.16884	.08850	.03408	.00957	.00191	.00026	.00002	.00000
32	.00977	.05520	.14287	.22411	.23729	.17866	.09809	.03957	.01164	.00243	.00034	.00003	.00000
33	.00818	.04836	.13101	.21510	.23837	.18785	.10795	.04557	.01403	.00307	.00045	.00004	.00000
34	.00683	.04223	.11966	.20547	.23816	.19630	.11798	.05210	.01677	.00384	.00059	.00006	.00000
35	.00569	.03675	.10885	.19537	.23669	.20392	.12810	.05912	.01990	.00476	.00077	.00008	.00000
36	.00472	.03188	.09862	.18491	.23402	.21062	.13822	.06664	.02343	.00586	.00099	.00010	.00000
37	.00391	.02755	.08899	.17422	.23022	.21633	.14823	.07462	.02739	.00715	.00126	.00013	.00001
38	.00323	.02373	.07999	.16342	.22536	.22100	.15802	.08302	.03180	.00866	.00159	.00018	.00001
39	.00265	.02036	.07161	.15261	.21953	.22457	.16751	.09180	.03668	.01042	.00200	.00023	.00001
40	.00218	.01741	.06385	.14189	.21284	.22703	.17658	.10090	.04204	.01246	.00249	.00030	.00002
41	.00178	.01484	.05671	.13135	.20538	.22835	.18513	.11027	.04789	.01479	.00308	.00039	.00002
42	.00145	.01259	.05016	.12107	.19725	.22854	.19308	.11984	.05424	.01746	.00379	.00050	.00003
43	.00118	.01065	.04418	.11110	.18857	.22761	.20032	.12953	.06107	.02048	.00463	.00064	.00004
44	.00095	.00897	.03876	.10150	.17944	.22558	.20678	.13926	.06839	.02388	.00563	.00080	.00005
45	.00077	.00752	.03385	.09233	.16996	.22250	.21238	.14895	.07617	.02770	.00680	.00101	.00007
46	.00061	.00628	.02944	.08361	.16025	.21841	.21706	.15849	.08438	.03195	.00816	.00126	.00009
47	.00049	.00523	.02550	.07537	.15038	.21338	.22076	.16780	.09300	.03665	.00975	.00157	.00012
48	.00039	.00433	.02198	.06764	.14047	.20747	.22343	.17678	.10199	.04184	.01159	.00194	.00015
49	.00031	.00357	.01886	.06041	.13060	.20077	.22505	.18533	.11129	.04752	.01370	.00239	.00019
50	.00024	.00293	.01611	.05371	.12085	.19336	.22559	.19336	.12085	.05371	.01611	.00293	.00024

TABLE 11 12 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES	10 TREES	11 TREES	12 TREES
51	.00019	.00239	.01370	.04752	.11129	.18533	.22505	.20077	.13060	.06041	.01886	.00357	.00031
52	.00015	.00194	.01159	.04184	.10199	.17678	.22343	.20747	.14047	.06764	.02198	.00433	.00039
53	.00012	.00157	.00975	.03665	.09300	.16780	.22076	.21338	.15038	.07537	.02550	.00523	.00049
54	.00009	.00126	.00816	.03195	.08438	.15849	.21706	.21841	.16025	.08361	.02944	.00628	.00061
55	.00007	.00101	.00680	.02770	.07617	.14895	.21238	.22250	.16996	.09233	.03385	.00752	.00077
56	.00005	.00080	.00563	.02388	.06839	.13926	.20678	.22558	.17944	.10150	.03876	.00897	.00095
57	.00004	.00064	.00463	.02048	.06107	.12953	.20032	.22761	.18857	.11110	.04418	.01065	.00118
58	.00003	.00050	.00379	.01746	.05424	.11984	.19308	.22854	.19725	.12107	.05016	.01259	.00145
59	.00002	.00039	.00308	.01479	.04789	.11027	.18513	.22835	.20538	.13135	.05671	.01484	.00178
60	.00002	.00030	.00249	.01246	.04204	.10090	.17658	.22703	.21284	.14189	.06385	.01741	.00218
61	.00001	.00023	.00200	.01042	.03668	.09180	.16751	.22457	.21953	.15261	.07161	.02036	.00265
62	.00001	.00018	.00159	.00866	.03180	.08302	.15802	.22100	.22536	.16342	.07999	.02373	.00323
63	.00001	.00013	.00126	.00715	.02739	.07462	.14823	.21633	.23022	.17422	.08899	.02755	.00391
64	.00000	.00010	.00099	.00586	.02343	.06664	.13822	.21062	.23402	.18491	.09862	.03188	.00472
65	.00000	.00008	.00077	.00476	.01990	.05912	.12810	.20392	.23669	.19537	.10885	.03675	.00569
66	.00000	.00006	.00059	.00384	.01677	.05210	.11798	.19630	.23816	.20547	.11966	.04223	.00683
67	.00000	.00004	.00045	.00307	.01403	.04557	.10795	.18785	.23837	.21510	.13101	.04836	.00818
68	.00000	.00003	.00034	.00243	.01164	.03957	.09809	.17866	.23729	.22411	.14287	.05520	.00977
69	.00000	.00002	.00026	.00191	.00957	.03408	.08850	.16884	.23488	.23235	.15515	.06279	.01165
70	.00000	.00001	.00019	.00149	.00780	.02911	.07925	.15850	.23114	.23970	.16779	.07118	.01384
71	.00000	.00001	.00014	.00114	.00629	.02465	.07041	.14775	.22608	.24600	.18069	.08043	.01641
72	.00000	.00001	.00010	.00087	.00503	.02068	.06203	.13672	.21973	.25112	.19372	.09057	.01941
73	.00000	.00000	.00007	.00065	.00397	.01717	.05417	.12555	.21215	.25493	.20678	.10165	.02290
74	.00000	.00000	.00005	.00048	.00310	.01412	.04687	.11434	.20340	.25729	.21969	.11369	.02696
75	.00000	.00000	.00004	.00035	.00239	.01147	.04015	.10324	.19358	.25810	.23229	.12671	.03168
76	.00000	.00000	.00002	.00026	.00182	.00921	.03403	.09236	.18279	.25726	.24440	.14072	.03713
77	.00000	.00000	.00002	.00018	.00136	.00730	.02851	.08181	.17118	.25470	.25580	.15571	.04344
78	.00000	.00000	.00001	.00013	.00101	.00570	.02359	.07170	.15887	.25035	.26628	.17165	.05071
79	.00000	.00000	.00001	.00009	.00073	.00439	.01926	.06212	.14605	.24419	.27558	.18849	.05909
80	.00000	.00000	.00000	.00006	.00052	.00332	.01550	.05315	.13288	.23622	.28347	.20616	.06872
81	.00000	.00000	.00000	.00004	.00036	.00247	.01228	.04486	.11954	.22649	.28967	.22453	.07977
82	.00000	.00000	.00000	.00002	.00025	.00180	.00955	.03731	.10622	.21506	.29392	.24345	.09242
83	.00000	.00000	.00000	.00001	.00016	.00128	.00729	.03052	.09312	.20206	.29595	.26272	.10689
84	.00000	.00000	.00000	.00001	.00011	.00089	.00545	.02451	.08041	.18763	.29551	.28208	.12341
85	.00000	.00000	.00000	.00001	.00007	.00060	.00397	.01928	.06828	.17198	.29236	.30122	.14224
86	.00000	.00000	.00000	.00000	.00004	.00039	.00281	.01482	.05690	.15534	.28628	.31974	.16367
87	.00000	.00000	.00000	.00000	.00002	.00025	.00193	.01109	.04640	.13801	.27709	.33716	.18803
88	.00000	.00000	.00000	.00000	.00001	.00015	.00128	.00805	.03691	.12031	.26469	.35292	.21567
89	.00000	.00000	.00000	.00000	.00001	.00009	.00081	.00564	.02853	.10259	.24902	.36632	.24699
90	.00000	.00000	.00000	.00000	.00000	.00005	.00049	.00379	.02131	.08523	.23013	.37657	.28243
91	.00000	.00000	.00000	.00000	.00000	.00002	.00028	.00242	.01527	.06863	.20818	.38272	.32248
92	.00000	.00000	.00000	.00000	.00000	.00001	.00015	.00145	.01041	.05318	.18349	.38365	.36767
93	.00000	.00000	.00000	.00000	.00000	.00000	.00007	.00080	.00665	.03927	.15652	.37809	.41860
94	.00000	.00000	.00000	.00000	.00000	.00000	.00003	.00040	.00391	.02723	.12797	.36453	.47592
95	.00000	.00000	.00000	.00000	.00000	.00000	.00001	.00017	.00205	.01733	.09879	.34128	.54036
96	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00006	.00091	.00975	.07021	.30635	.61271
97	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00002	.00031	.00452	.04380	.25751	.69384
98	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00007	.00147	.02157	.19218	.78472
99	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00020	.00597	.10744	.88638

TABLE 12 13 SEEDS PER CONTAINER

GERMINATION	PROBABILITY OF OCCURANCE													
PERCENT	0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES	10 TREES	11 TREES	12 TREES	13 TREES
1	.87752	.11523	.00698	.00026	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
2	.76902	.20403	.02498	.00187	.00010	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
3	.67303	.27060	.05021	.00569	.00044	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
4	.58820	.31861	.07965	.01217	.00127	.00010	.00001	.00000	.00000	.00000	.00000	.00000	.00000	.00000
5	.51334	.35123	.11092	.02140	.00282	.00027	.00002	.00000	.00000	.00000	.00000	.00000	.00000	.00000
6	.44737	.37122	.14217	.03327	.00531	.00061	.00005	.00000	.00000	.00000	.00000	.00000	.00000	.00000
7	.38929	.38092	.17203	.04748	.00893	.00121	.00012	.00001	.00000	.00000	.00000	.00000	.00000	.00000
8	.33825	.38237	.19950	.06361	.01383	.00216	.00025	.00002	.00000	.00000	.00000	.00000	.00000	.00000
9	.29345	.37730	.22389	.08119	.02007	.00357	.00047	.00005	.00000	.00000	.00000	.00000	.00000	.00000
10	.25419	.36716	.24477	.09972	.02770	.00554	.00082	.00009	.00001	.00000	.00000	.00000	.00000	.00000
11	.21982	.35320	.26192	.11870	.03668	.00816	.00134	.00017	.00002	.00000	.00000	.00000	.00000	.00000
12	.18979	.33645	.27527	.13764	.04692	.01152	.00209	.00029	.00003	.00000	.00000	.00000	.00000	.00000
13	.16359	.31777	.28490	.15609	.05831	.01568	.00312	.00047	.00005	.00000	.00000	.00000	.00000	.00000
14	.14076	.29789	.29096	.17367	.07068	.02071	.00450	.00073	.00009	.00001	.00000	.00000	.00000	.00000
15	.12091	.27737	.29369	.19003	.08384	.02663	.00627	.00111	.00015	.00001	.00000	.00000	.00000	.00000
16	.10366	.25669	.29336	.20489	.09757	.03345	.00850	.00162	.00023	.00002	.00000	.00000	.00000	.00000
17	.08872	.23623	.29030	.21802	.11164	.04116	.01124	.00230	.00035	.00004	.00000	.00000	.00000	.00000
18	.07578	.21626	.28483	.22926	.12581	.04971	.01455	.00319	.00053	.00006	.00001	.00000	.00000	.00000
19	.06461	.19702	.27729	.23849	.13986	.05905	.01847	.00433	.00076	.00010	.00001	.00000	.00000	.00000
20	.05498	.17867	.26801	.24567	.15355	.06910	.02303	.00576	.00108	.00015	.00001	.00000	.00000	.00000
21	.04668	.16132	.25729	.25078	.16666	.07974	.02826	.00751	.00150	.00022	.00002	.00000	.00000	.00000
22	.03956	.14504	.24546	.25385	.17900	.09088	.03418	.00964	.00204	.00032	.00004	.00000	.00000	.00000
23	.03345	.12989	.23278	.25495	.19039	.10236	.04077	.01218	.00273	.00045	.00005	.00000	.00000	.00000
24	.02822	.11586	.21952	.25418	.20067	.11406	.04803	.01517	.00359	.00063	.00008	.00001	.00000	.00000
25	.02376	.10295	.20590	.25165	.20971	.12583	.05592	.01864	.00466	.00086	.00012	.00001	.00000	.00000
26	.01995	.09114	.19213	.24752	.21741	.13750	.06441	.02263	.00596	.00116	.00016	.00002	.00000	.00000
27	.01672	.08039	.17839	.24193	.22370	.14893	.07344	.02716	.00754	.00155	.00023	.00002	.00000	.00000
28	.01397	.07065	.16484	.23505	.22852	.15997	.08295	.03226	.00941	.00203	.00032	.00003	.00000	.00000
29	.01165	.06186	.15161	.22706	.23186	.17047	.09284	.03792	.01162	.00264	.00043	.00005	.00000	.00000
30	.00969	.05398	.13881	.21813	.23371	.18029	.10302	.04415	.01419	.00338	.00058	.00007	.00000	.00000
31	.00804	.04693	.12652	.20842	.23410	.18931	.11340	.05095	.01717	.00429	.00077	.00009	.00001	.00000
32	.00665	.04066	.11481	.19811	.23307	.19742	.12387	.05829	.02057	.00538	.00101	.00013	.00001	.00000
33	.00548	.03510	.10374	.18735	.23069	.20453	.13432	.06616	.02444	.00669	.00132	.00018	.00001	.00000
34	.00451	.03020	.09333	.17630	.22705	.21054	.14461	.07450	.02878	.00824	.00170	.00024	.00002	.00000
35	.00370	.02588	.08361	.16508	.22223	.21539	.15464	.08327	.03363	.01006	.00217	.00032	.00003	.00000
36	.00302	.02210	.07459	.15384	.21634	.21904	.16428	.09241	.03899	.01218	.00274	.00042	.00004	.00000
37	.00246	.01880	.06626	.14268	.20950	.22147	.17342	.10185	.04486	.01464	.00344	.00055	.00005	.00000
38	.00200	.01594	.05861	.13171	.20182	.22265	.18195	.11152	.05126	.01746	.00428	.00072	.00007	.00000
39	.00162	.01346	.05162	.12102	.19343	.22261	.18976	.12132	.05818	.02066	.00528	.00092	.00010	.00000
40	.00131	.01132	.04528	.11068	.18446	.22135	.19676	.13117	.06559	.02429	.00648	.00118	.00013	.00001
41	.00105	.00948	.03954	.10075	.17503	.21893	.20285	.14097	.07347	.02836	.00788	.00149	.00017	.00001
42	.00084	.00791	.03438	.09128	.16526	.21540	.20797	.15060	.08179	.03290	.00953	.00188	.00023	.00001
43	.00067	.00658	.02976	.08232	.15526	.21082	.21206	.15997	.09051	.03793	.01145	.00236	.00030	.00002
44	.00053	.00544	.02565	.07389	.14515	.20528	.21505	.16897	.09957	.04346	.01366	.00293	.00038	.00002
45	.00042	.00448	.02200	.06601	.13503	.19886	.21694	.17749	.10892	.04951	.01620	.00362	.00049	.00003
46	.00033	.00368	.01879	.05869	.12499	.19165	.21768	.18543	.11847	.05607	.01910	.00444	.00063	.00004
47	.00026	.00300	.01597	.05193	.11513	.18377	.21729	.19269	.12816	.06314	.02240	.00542	.00080	.00005
48	.00020	.00244	.01351	.04572	.10551	.17531	.21577	.19917	.13789	.07071	.02611	.00657	.00101	.00007
49	.00016	.00197	.01137	.04005	.09621	.16639	.21315	.20479	.14757	.07877	.03027	.00793	.00127	.00009
50	.00012	.00159	.00952	.03491	.08728	.15710	.20947	.20947	.15710	.08728	.03491	.00952	.00159	.00012

TABLE 12 13 SEEDS PER CONTAINER

GERMINATION PERCENT	PROBABILITY OF OCCURANCE 0 TREES	1 TREE	2 TREES	3 TREES	4 TREES	5 TREES	6 TREES	7 TREES	8 TREES	9 TREES	10 TREES	11 TREES	12 TREES	13 TREES
51	.00009	.00127	.00793	.03027	.07877	.14757	.20479	.21315	.16639	.09621	.04005	.01137	.00197	.00016
52	.00007	.00101	.00657	.02611	.07071	.13789	.19917	.21577	.17531	.10551	.04572	.01351	.00244	.00020
53	.00005	.00080	.00542	.02240	.06314	.12816	.19269	.21729	.18377	.11513	.05193	.01597	.00300	.00026
54	.00004	.00063	.00444	.01910	.05607	.11847	.18543	.21768	.19165	.12499	.05869	.01879	.00368	.00033
55	.00003	.00049	.00362	.01620	.04951	.10892	.17749	.21694	.19886	.13503	.06601	.02200	.00448	.00042
56	.00002	.00038	.00293	.01366	.04346	.09957	.16897	.21505	.20528	.14515	.07389	.02565	.00544	.00053
57	.00002	.00030	.00236	.01145	.03793	.09051	.15997	.21206	.21082	.15526	.08232	.02976	.00658	.00067
58	.00001	.00023	.00188	.00953	.03290	.08179	.15060	.20797	.21540	.16526	.09128	.03438	.00791	.00084
59	.00001	.00017	.00149	.00788	.02836	.07347	.14097	.20285	.21893	.17503	.10075	.03954	.00948	.00105
60	.00001	.00013	.00118	.00648	.02429	.06559	.13117	.19676	.22135	.18446	.11068	.04528	.01132	.00131
61	.00000	.00010	.00092	.00528	.02066	.05818	.12132	.18976	.22261	.19343	.12102	.05162	.01346	.00162
62	.00000	.00007	.00072	.00428	.01746	.05126	.11152	.18195	.22265	.20182	.13171	.05861	.01594	.00200
63	.00000	.00005	.00055	.00344	.01464	.04486	.10185	.17342	.22147	.20950	.14268	.06626	.01880	.00246
64	.00000	.00004	.00042	.00274	.01218	.03899	.09241	.16428	.21904	.21634	.15384	.07459	.02210	.00302
65	.00000	.00003	.00032	.00217	.01006	.03363	.08327	.15464	.21539	.22223	.16508	.08361	.02588	.00370
66	.00000	.00002	.00024	.00170	.00824	.02878	.07450	.14461	.21054	.22705	.17630	.09333	.03020	.00451
67	.00000	.00001	.00018	.00132	.00669	.02444	.06616	.13432	.20453	.23069	.18735	.10374	.03510	.00548
68	.00000	.00001	.00013	.00101	.00538	.02057	.05829	.12387	.19742	.23307	.19811	.11481	.04066	.00665
69	.00000	.00001	.00009	.00077	.00429	.01717	.05095	.11340	.18931	.23410	.20842	.12652	.04693	.00804
70	.00000	.00000	.00007	.00058	.00338	.01419	.04415	.10302	.18029	.23371	.21813	.13881	.05398	.00969
71	.00000	.00000	.00005	.00043	.00264	.01162	.03792	.09284	.17047	.23186	.22706	.15161	.06186	.01165
72	.00000	.00000	.00003	.00032	.00203	.00941	.03226	.08295	.15997	.22852	.23505	.16484	.07065	.01397
73	.00000	.00000	.00002	.00023	.00155	.00754	.02716	.07344	.14893	.22370	.24193	.17839	.08039	.01672
74	.00000	.00000	.00002	.00016	.00116	.00596	.02263	.06441	.13750	.21741	.24752	.19213	.09114	.01995
75	.00000	.00000	.00001	.00012	.00086	.00466	.01864	.05592	.12583	.20971	.25165	.20590	.10295	.02376
76	.00000	.00000	.00001	.00008	.00063	.00359	.01517	.04803	.11406	.20067	.25418	.21952	.11586	.02822
77	.00000	.00000	.00000	.00005	.00045	.00273	.01218	.04077	.10236	.19039	.25495	.23278	.12989	.03345
78	.00000	.00000	.00000	.00004	.00032	.00204	.00964	.03418	.09088	.17900	.25385	.24546	.14504	.03956
79	.00000	.00000	.00000	.00002	.00022	.00150	.00751	.02826	.07974	.16666	.25078	.25729	.16132	.04668
80	.00000	.00000	.00000	.00001	.00015	.00108	.00576	.02303	.06910	.15355	.24567	.26801	.17867	.05498
81	.00000	.00000	.00000	.00001	.00010	.00076	.00433	.01847	.05905	.13986	.23849	.27729	.19702	.06461
82	.00000	.00000	.00000	.00001	.00006	.00053	.00319	.01455	.04971	.12581	.22926	.28483	.21626	.07578
83	.00000	.00000	.00000	.00000	.00004	.00035	.00230	.01124	.04116	.11164	.21802	.29030	.23623	.08872
84	.00000	.00000	.00000	.00000	.00002	.00023	.00162	.00850	.03345	.09757	.20489	.29336	.25669	.10366
85	.00000	.00000	.00000	.00000	.00001	.00015	.00111	.00627	.02663	.08384	.19003	.29369	.27737	.12091
86	.00000	.00000	.00000	.00000	.00001	.00009	.00073	.00450	.02071	.07068	.17367	.29096	.29789	.14076
87	.00000	.00000	.00000	.00000	.00000	.00005	.00047	.00312	.01568	.05831	.15609	.28490	.31777	.16359
88	.00000	.00000	.00000	.00000	.00000	.00003	.00029	.00209	.01152	.04692	.13764	.27527	.33645	.18979
89	.00000	.00000	.00000	.00000	.00000	.00002	.00017	.00134	.00816	.03668	.11870	.26192	.35320	.21982
90	.00000	.00000	.00000	.00000	.00000	.00001	.00009	.00082	.00554	.02770	.09972	.24477	.36716	.25419
91	.00000	.00000	.00000	.00000	.00000	.00000	.00005	.00047	.00357	.02007	.08119	.22389	.37730	.29345
92	.00000	.00000	.00000	.00000	.00000	.00000	.00002	.00025	.00216	.01383	.06361	.19950	.38237	.33825
93	.00000	.00000	.00000	.00000	.00000	.00000	.00001	.00012	.00121	.00893	.04748	.17203	.38092	.38929
94	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00005	.00061	.00531	.03327	.14217	.37122	.44737
95	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00002	.00027	.00282	.02140	.11092	.35123	.51334
96	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00001	.00010	.00127	.01217	.07965	.31861	.58820
97	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00002	.00044	.00569	.05021	.27060	.67303
98	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00010	.00187	.02498	.20403	.76902
99	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00001	.00026	.00698	.11523	.87752

Appendix 4

Useful forms for greenhouse nursery record keeping.

1. Worksheet for calculation of fertilizer stock solutions.—See section 13.6 for instructions on how to use.

2. Fertilizer and irrigation record.—Fertilizing may or may not be done at each watering. EC and pH may or may not be taken at each fertilizing, although it is recommended that these readings be taken each time. Fertilizer type would be "high N," "low N," 15-10-30, etc. Several types of moisture sensor may be used, including a weighing scale, pressure bomb, bimetal probe, or educated finger. See section 6.56 for details.

3. Control settings.—This sheet should be posted where anyone who needs to know can tell quickly what greenhouse conditions are expected to be.

4. Growth record.—Seedlings should be sampled periodically during their growth. Measurements may be supplemented by pictures of seedlings or herbarium specimens.

5. Growing schedule.—Instructions for use and examples are in section 15, and additional examples are in appendix 2.

6. Daily Log (not shown).—This need not take any particular form, but should be a narrative of events and conditions as they occur. It will be most permanent if a bound log book is used.

WORKSHEET FOR CALCULATION OF FERTILIZER STOCK SOLUTION

Line 1	2	3	4	5	6	7	8	9	10	11
	Nutrient Elements (ppm)							Total	Stock soln. x ____	Cpd. com-pat.
	(NO_3) N	(NH_4) N	P	K	S	Ca	Mg	Cpd mg/l		
1. Target Conc.										
2. Water anal.										
3. Net to Add										
Cpds. used:	–	–	–	–	–	–	–	–	–	–
4.										
5.										
6.										
7										
8.										
9										
10. Total										
	Fe	Cl	B	Mn	Zn	Cu	Mo		x____	
11. Target Conc.										
12. Water anal.										
13. Net to Add										
14.										
15.										
16.										
17.										
18.										
19.										
20.										

FERTILIZER and IRRIGATION RECORD

Greenhouse No. ______ Crop ____________________

Mo./Yr. ______________ ____________________

Date	Moisture sensor reading	Water temp.	Length of watering time	Fertilizer type	Irrigation solution		Leachate		Remarks Initials
					pH	EC	pH	EC	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									

CONTROL SETTINGS

Greenhouse No.

Crop ____________

	Day Temperature							Night Temperature											
	Cooling stage				Heating stage			Cooling stage				Heating stage							
Date	3	2	1	N	1	2	3	3	2	1	N	1	2	3	Rel. Hum.	CO_2	Light at night	Watering cycle	Comments Initials

GROWTH RECORD

Greenhouse No. ______ Species ____________________

Seed lot ____________________

Date	Height	Caliper	Weight	Comments

Species________________ Container________________ Outplanting______________ Location________________ Cycle______ __________

Source________________________

Season		
Growth stage		
Day temp (°F)	Optimum Permissible	
Night temp (°F)	Optimum Permissible	
Rel. Hum. (%)	Optimum Permissible	
Daylight		
Supplemental light		
Water		
Fertilizer		
CO_2 level		
Operations		

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This guide to development and operation of a greenhouse nursery for container grown forest tree seedlings will help managers decide if a nursery should be built and gives criteria for selecting site, building design and layout, hardware, controls, container, and growing medium. It discusses environmental factors that can be controlled, optimum conditions for growth, and how to achieve them. Growing schedules, greenhouse cultural practices, nursery management, and troubleshooting problems are also discussed.

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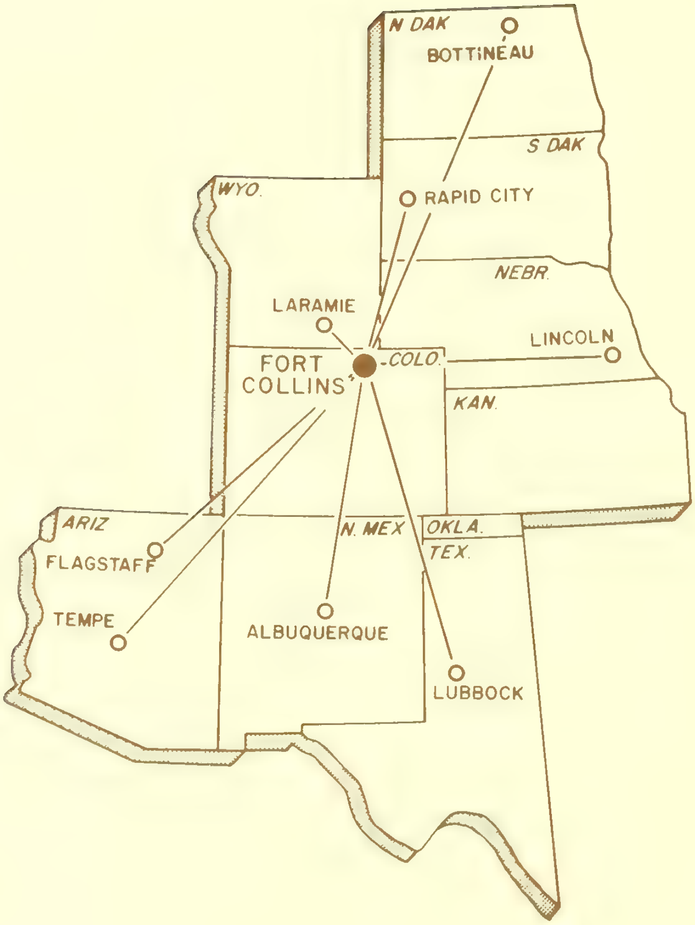
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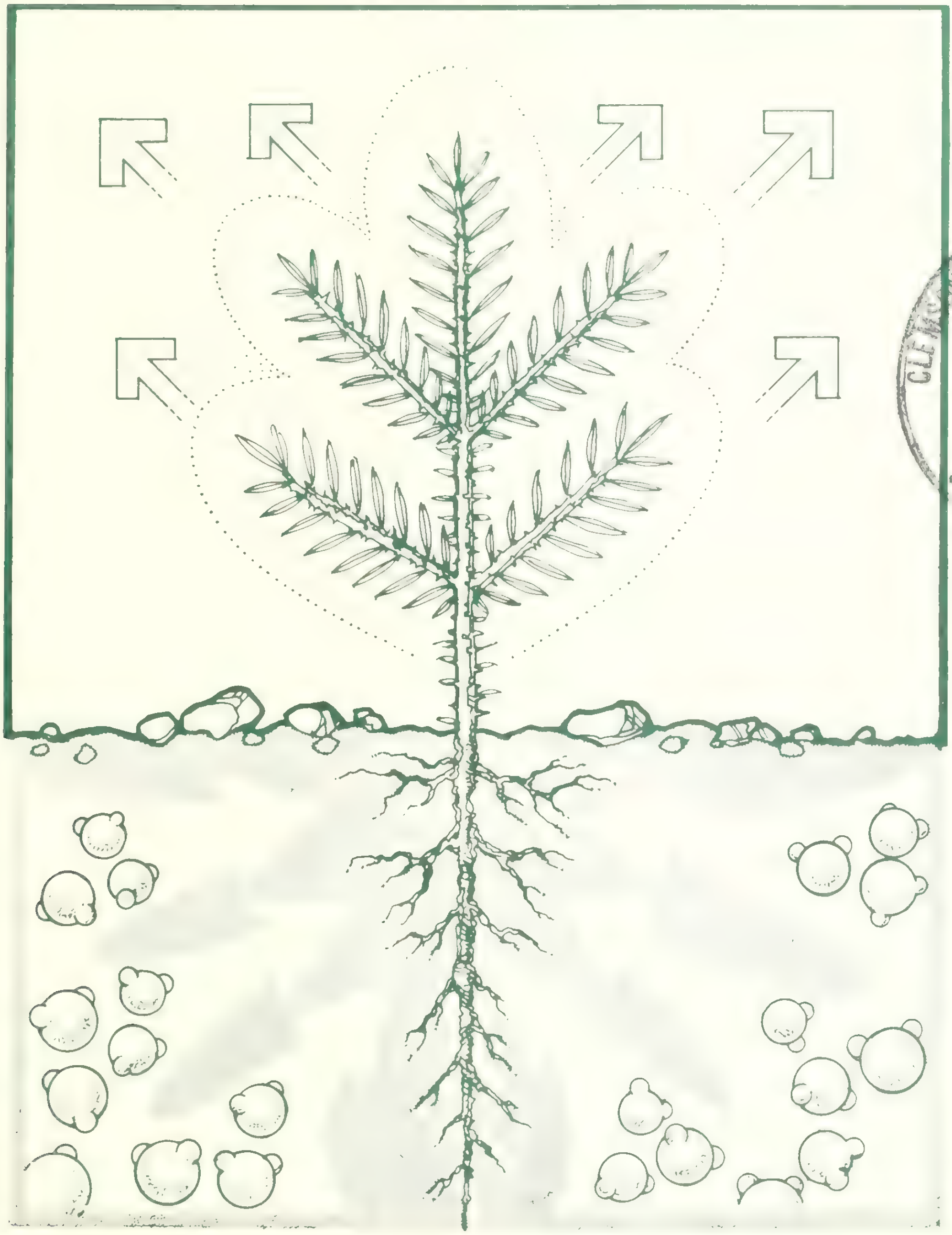
Monitoring Irrigation in Western Forest Tree Nurseries

Stephen E. McDonald and Steven W. Running



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Abstract

This report reviews instruments available for soil and seedling water measurement, and makes recommendations for improvement of irrigation monitoring techniques. Guidelines for use of the pressure bomb to measure seedling water stress and interpretation of the results are included.

Keywords: Tree nursery, greenhouse, irrigation, pressure bomb, water stress.

General Technical Report RM-61

April 1979

Monitoring Irrigation in Western Forest Tree Nurseries

Stephen E. McDonald and Steven W. Running[1]

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[1] *Western Nursery and Greenhouse Specialist, State and Private Forestry, USDA Forest Service, Rocky Mountain Region, Lakewood, Colo., and Research Forester, Rocky Mountain Forest and Range Experiment Station, central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

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Monitoring Irrigation in Western Forest Tree Nurseries

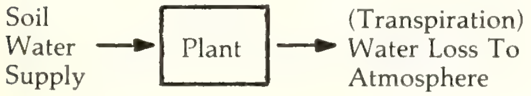
Stephen E. McDonald and Steven W. Running

Seedling Water Relations

Effects of Water Stress

Numerous studies have documented adverse effects of water stress on physiological and biochemical plant functions. Cell elongation and cell division, important factors in forest tree seedling growth, are the first plant functions to be retarded by low level water stresses (Hsiao et al. 1976).

Plant water transport can be viewed as a simple input-output system, with soil water as the input and plant transpiration to the atmosphere as the output.



Under optimal conditions, transpired water loss is replenished by root water uptake during the course of a day, although some lag between transpiration and root uptake is normal due to a lag in transmission of water stress through the plant.

Diurnal effects.—When atmospheric evaporative demand exceeds the ability of the root system to provide water, the result is short-term water stress. Atmospheric evaporative demand is generated primarily by increasing air temperature and decreasing humidity, although radiation intensity and windspeed contribute less directly.

At constant relative humidity, the evaporative demand increases exponentially with air temperature, not linearly, because the atmosphere can hold more water vapor as air temperature rises (fig. 1). Consequently, as air temperature rises, evaporative demand can become very high and cause significant short-term water stress even with well-watered soil. The nursery manager can moderate evaporative demand by shading and midday overhead sprinkling. These measures may or may not be worthwhile depending on the nursery's location and the tree species being grown.

Soil water content effects.—Low soil water content also will induce plant water stress. This variable can be controlled by the nursery manager. The ability of a plant root system to extract water from soil depends on the difference between water potential of the plant root system and water potential of the soil. Total water potential is a physical-chemical parameter with a number of components. These components quantify soil particle-water attractions, salt solution influences, plant xylem tension, and cell turgor effects. Kramer (1969) provides a complete definition of water potential. In general, optimum plant or soil water conditions are at a water potential near 0 bar (1 bar = 14.7 pounds per square inch). As water stress increases, water potential decreases, becoming more negative. Mild midday tree seedling water stress might be -7 to -10 bars.

Soil water potential decreases as soil water content drops. As figure 2 demonstrates, the relationship is both nonlinear and changes with soil texture

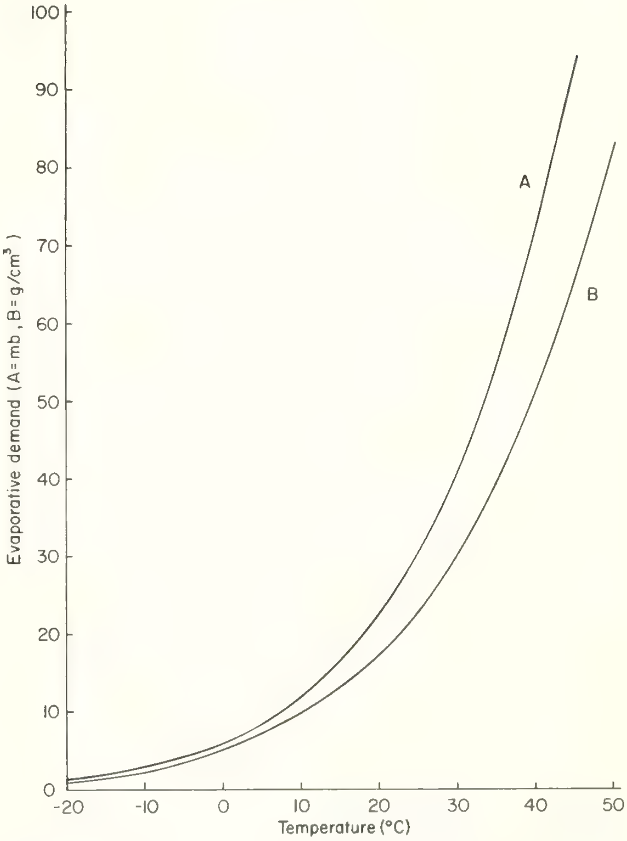


Figure 1.—Effect of air temperature on the ability of the atmosphere to hold water vapor, expressed in two frequently encountered units: A — saturation vapor pressure in millibars, and B — saturation vapor density in grams per cubic centimeter of air (x10^{6}).

(Hausenbuiller 1972). Such soil moisture retention curves are very useful at tree nurseries and can be acquired from soil testing labs for $25 to $30. Notice, for the sandy-loam soil in figure 2, 77% of the water can be removed before soil moisture tension exceeds -0.8 bar. Any additional water depletion increases tension rapidly. Consequently, to maximize water use efficiency while minimizing plant water stress, plants should be irrigated at soil water potentials of no lower than -0.5 to -0.8 bar. This is within the range of soil tensiometer measurement capabilities.

Shoot/Root Ratio

The shoot/root ratio significantly affects development of plant water stress. Increasing root area of a seedling with a constant top leaf area allows it to better withstand high evaporative demand and low soil water potential, because total root water uptake is increased.

Seedlings cultured (through water stressing or top pruning) or selected (graded) for lower shoot/root ratios should tolerate water stress following outplanting better than those that are not. Lopushinsky and Beebe (1976) have reported on the operational significance of these ideas.

Plant Water Potential

Internal plant water potential is dynamic. It changes both diurnally and seasonally, and integrates effects of soil water potential and atmospheric evaporative demand with plant response. The parameter produced is the single most useful measure of water stress in the plant. Figure 3 illustrates expected diurnal patterns of plant water potential in nursery seedlings under different conditions. Pre-sunrise water potential readings are indirect measures of soil water potential and are the

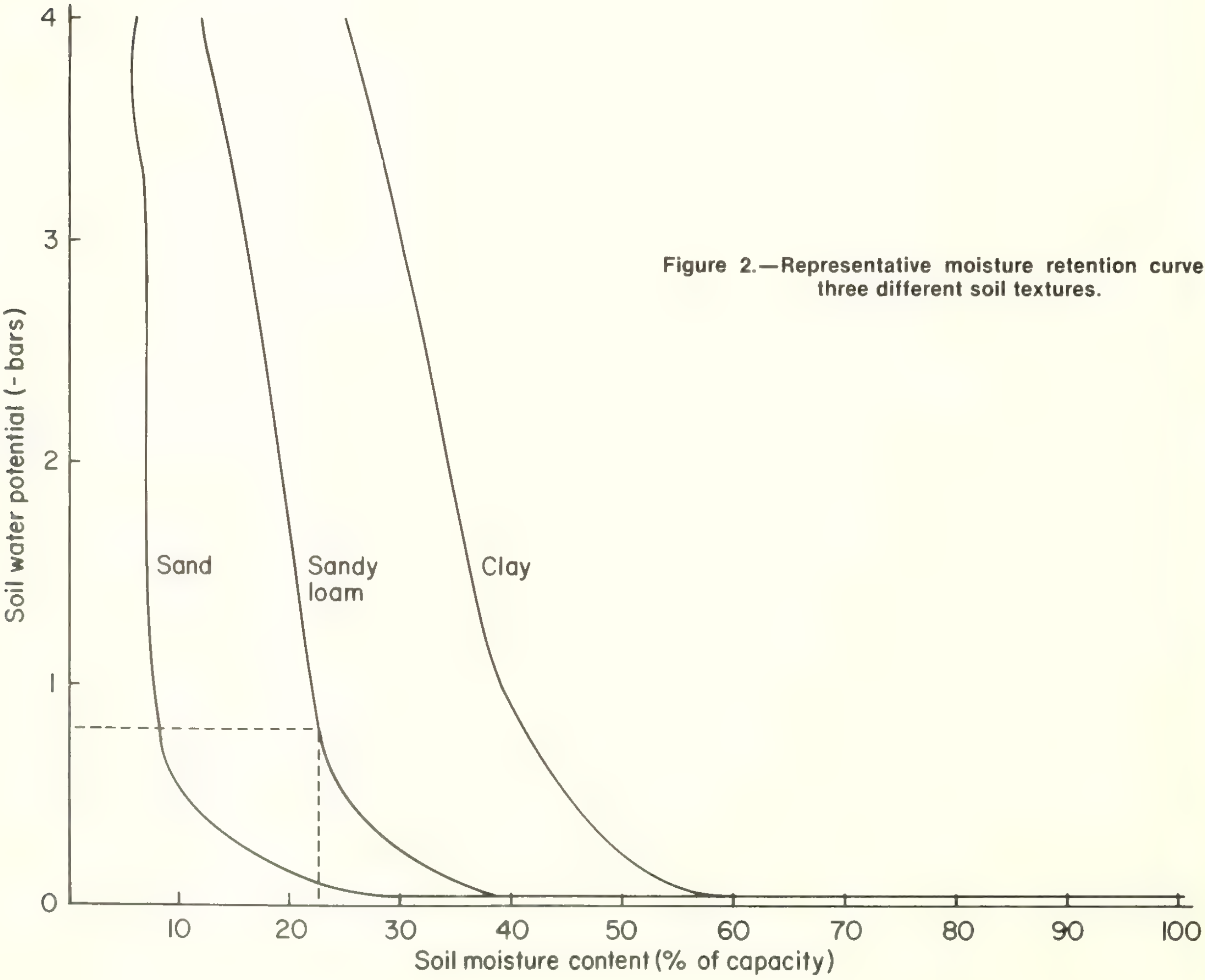


Figure 2.—Representative moisture retention curves fo
three different soil textures.

most stable measures of plant water potential that can be acquired. When taking pre-sunrise measurements, it should be completely dark. Generally, if it is light enough to walk without a flashlight, it is too late.

Plant water potential usually drops to a plateau between about 0900 and 1100 in summer and remains roughly at that level until late afternoon. This midday plateau is the second most stable time to measure plant water potential. However, interpretation of midday measurements is more difficult, because they reflect soil water potential, atmospheric evaporative demand, and physiological plant response through stomatal closure. Even under well-watered soil conditions plant water potential may remain in the range of -7 to -9 bars on a cool humid day but on a hot dry day may drop to -9 to -12 bars (fig. 3). As soil water is depleted, the midday plateau may drop to -15 bars or lower. Without irrigation, the reading will continue to drop until the plant dies at values of -40 to -50 bars. Figure 4 illustrates that, as soil water potential decreases, first midday then pre-sunrise plant water potential decreases (Slayter 1967). Generally, when midday plant water potential reaches -12 to -15 bars, water stress is probably beginning to impair growth. The time required to reach this water stress level depends on soil water available to each seedling and evaporative demand.

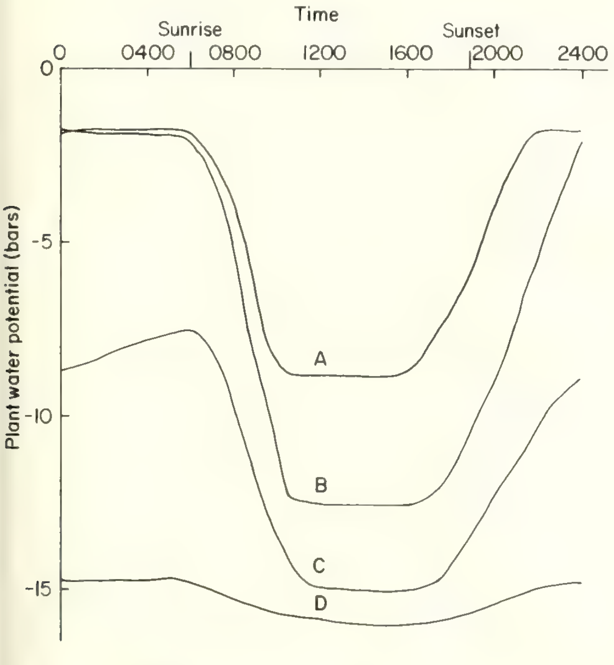


Figure 3.—Diurnal patterns of plant water potential for a nursery seedling under varying conditions of soil and atmospheric water stress. A — low soil water tension and low evaporative demand; B — low soil water tension and high evaporative demand; C — high soil water tension and high evaporative demand; D — extreme plant water stress.

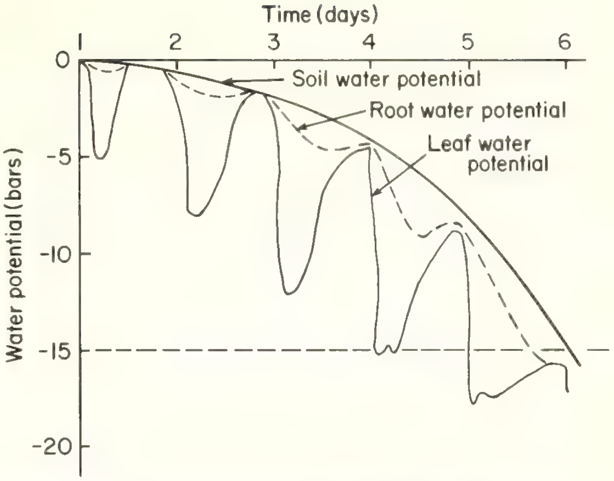


Figure 4.—The influence of decreasing soil water potential on development of plant water stress.

Variability in plant water potential at midday is significantly greater than at pre-sunrise. When using plant water potential measurements for water stress monitoring in outdoor nurseries, the effect of changing evaporative demand on seedling midday water potential must be accounted for. Seedlings in a greenhouse with less climatic variability should produce more consistent readings. Absolute variation in water potentials depends on tree species, seedling age, phenological stage, and other factors. Consequently, while some indication of expected values is given here, it is best for each nursery to do some tests under its conditions.

Methods of Irrigation Monitoring

Visual and Tactile Irrigation Monitoring

This method consists of looking at and feeling plants and soil to determine irrigation need. Hardwood seedlings are sometimes used as indicators (wilting), but more often, the water content of the soil is assessed either at the surface, in the root zone, or both, by eye and touch. There are, however, problems with the visual and tactile approach. They are subjective, since the observations are not based on the indications of a quantifiable mechanical or chemical procedure. The method requires experience and judgement on the part of the irrigator. One rule of thumb is:

> "When the water in the soil glistens, the soil is wetter than field capacity. When it is impossible to mold a ball of soil, it has a soil moisture tension of less than one (-1) bar. When the soil has a light color, it is drier than the hygroscopic point. At the wilting point the soil is crumbly, feels slightly

> moist, and has a dark color (though somewhat lighter than at one atmospheric tension)." (Kohnke 1968)

A more detailed version of this is provided in table 1. The idea of irrigating when a ball of soil can no longer be formed is imprecise and will certainly vary from soil to soil. Observations should be gaged against gravimetric samples or tensiometer readings. For container nurserymen, the first problem is getting to the proper part of the medium. Few containers can be opened. Keeping the growing medium at, or near, field capacity (about −0.3 bar) is recommended (Goodwin 1975, Tinus 1970).

The other major problem with the visual-tactile method is personnel. The individual checking irrigation must be experienced, observant, and methodical.

The visual-tactile method has some advantages: (1) no mechanical equipment that can fail is relied on, and (2) the irrigator is forced to closely observe the soil and plants and determine the need for irrigation.

Of 99 nurseries checked nationwide, nearly all determine irrigating schedules by visual observations of soil dryness (Abbott and Fitch 1977). Very few nurseries use instruments to measure soil moisture. The visual-tactile method should be accompanied by a mechanical method for calibration, continuity, and quantification.

Weight Loss

Weighing seedling containers is a useful irrigation monitoring practice in containerized seedling nurseries. It is used in about 25% of western container nurseries (McDonald 1978). When the weight of a filled container declines to some predetermined percentage of the saturated weight, the crop is irrigated. This percentage is often around 75-80% of the saturated weight. A moisture tension curve similar to figure 2 can be developed for the medium used.

The weighing procedure can be automated by placing a representative container on a weighing device that electrically turns on the water when the weight of the container falls below a certain point (White and Shaw 1966). This method becomes less accurate as seedlings grow and their weight confounds the process. Weighing is useful for keeping growing medium damp, but is poorly related to plant water stress.

Electrical Resistance Blocks

Electrical resistance blocks (fig. 5) are made of some porous material like gypsum, plaster of paris, or fiberglass (Bouyoucous 1954). The water content

Table 1.—Visual-tactile guidelines to soil water content

Available soil moisture remaining	Feel or appearance of soil			
	Coarse texture	**Moderately coarse texture**	**Medium texture**	**Fine and very fine texture**
0% to 25%	Dry, loose, single grained, flows through fingers.	Dry, loose, flows through fingers.	Powdery dry, sometimes slightly crusted but easily broken down into powdery condition.	Hard, baked, cracked, sometimes has loose crumbs on surface.
25% to 50%	Appears to be dry, will not form a ball with pressure.[1]	Appears to be dry, will not form a ball.[1]	Somewhat crumbly but holds together from pressure.	Somewhat pliable, ball under pressure.[1]
50% to 75%	Appears to be dry, will not form a ball with pressure.	Tends to ball under pressure but seldom holds together.	Forms a ball somewhat plastic, will sometimes stick slightly with pressure.	Forms a ball, ribbons out between thumb and forefinger.
75% to field capacity (100%)	Tends to stick together slightly, sometimes forms a very weak ball under pressure.	Forms weak ball, breaks easily, will not stick.	Forms a ball, is very pliable, sticks readily if relatively high in clay.	Easily ribbons out between fingers, has slick feeling.
At field capacity (100%)	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.

[1] *Ball is formed by squeezing a handful of soil very firmly.*

of these blocks changes with soil moisture content. The electrical resistance between two electrodes, buried in these blocks, varies with water content of the block. Readings on a resistance bridge connected to these electrodes are converted to an index of soil moisture content. Consequently, electrical resistance blocks provide only an indirect measure of soil moisture content which is not directly related to internal plant moisture stress. Resistance is also decreased by salt in the soil and increasing temperature, so, calibration is a problem. Seedling roots must be near the blocks for readings to be meaningful.

Resistance blocks are sensitive over a range from -0.5 to -15 bars of matric potential, so, they are effective in dry soil. The electrical resistance is calibrated against actual soil moisture content by taking readings on a soil at various moistures, finding the soil moisture content by the gravimetric method, and plotting the curve. This method is of little use in forest tree seedling containers, because the blocks are influenced by fertilizer solutions and usually are too large to fit in the container.

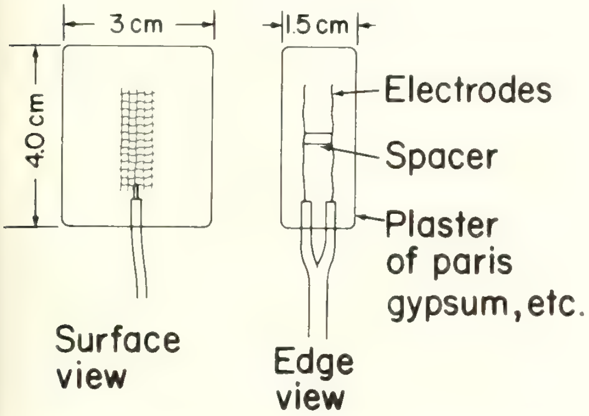


Figure 5.—Diagram of an electrical resistance block.

Tensiometers

Direct field measurements of the matric, or capillary, potential of a soil can be made with tensiometers (fig. 6). They are used in about 10% of western bareroot nurseries (McDonald 1978). A porous cup filled with water is buried in the soil and connected to a manometer or vacuum gage. The gage registers the pressure drop on water in the porous cup, which is in equilibrium with the matric potential of water in the soil. Tensiometers work well in wet soils, but when matric potential drops to -0.8 bar, air begins to enter the porous cup, and the tensiometer becomes useless. In the sandy loam shown in figure 2, the range in soil moisture tension from 0 to -0.8 bar covers about 77% of the water available in the soil. Consequently, the instrument really covers the prime irrigating range for nurseries. Although the tensiometer measures matric potential in the soil directly, it still provides only indirect inferences about internal plant moisture stress.

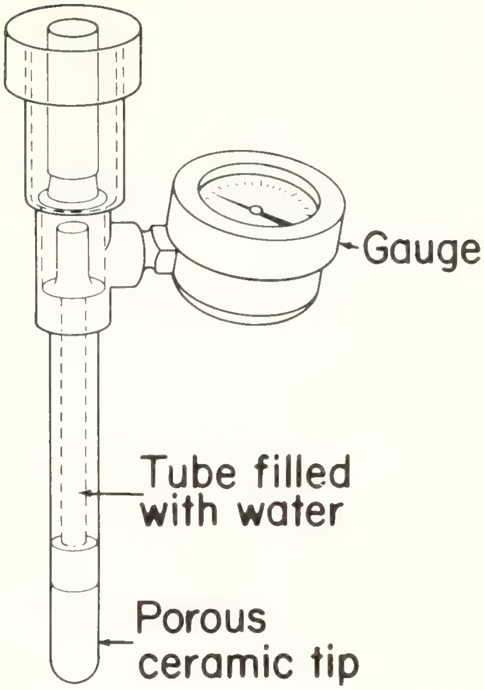


Figure 6.—Diagram of a soil tensiometer.

Pressure Bomb

The pressure bomb is the quickest, most foolproof method of measuring plant water potential in seedlings (Scholander et al. 1965). They are currently used in about 10-15% of western tree nurseries (McDonald 1978). A small twig or needle is cut from the seedling and placed in a steel chamber with the cut end protruding from the lid (fig. 7). A useful analogy is to think of the water column in a seedling as a rubber band. As water stress increases in the seedling, this rubber band is stretched. When the twig or needle is cut from the seedling, the tension on that rubber band water column is released, so, the water shrinks back from the cut surface. By slowly applying pressure to the cut twig in the chamber, water will be forced back to the cut surface by a pressure equal to the tension originally on that water column. By reading the pressure gage the instant water appears at the cut surface, and converting (14.7 pounds per square inch is equal to about 1 bar), the plant water potential is obtained.

Certain precautions are important in using this instrument. First, the sample should be measured within 1 minute, preferably instantly after cutting. Second, the pressure should be increased slowly, at about 3 pounds per square inch per second. Third, it is best if the size of the cut sample is consistent. Fourth, the cut end should not protrude more than 1 cm from the gasket. Read Ritchie and Hinckley (1975) before using the pressure bomb for seedling water stress measurements.

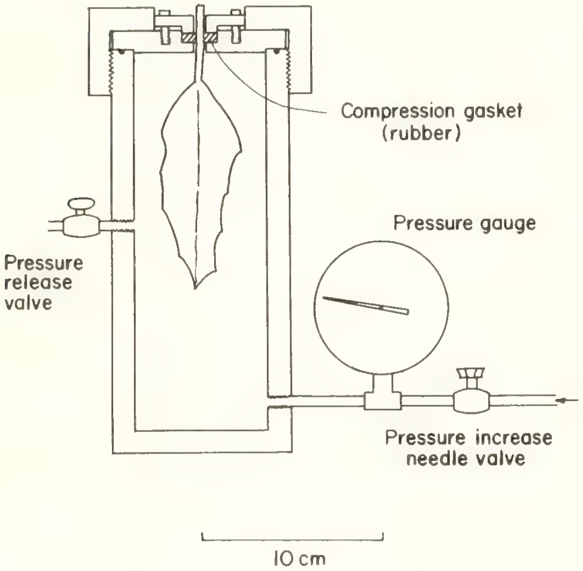


Figure 7.—Diagram of a pressure bomb.

Other Methods

Gravimetric samples are weighed, then dried in an oven, at about 105° C, until the weight becomes constant. The weight difference is considered water. The gravimetric method (weighing, then drying and reweighing the soil) normally takes too long for everyday use. However, it is very useful for calibration of other methods.

A few nurseries irrigate according to a "time schedule" or "water budget." The term "water budget" really refers to calculation of consumption. This is the water lost to evaporation and transpiration, which can vary with a great number of factors. The local use rates for most agricultural crops have been worked out, so, good consumptive use indexes exist for them. For tree nurseries, there appears to be little opportunity for practical application of this method. More precision is needed. However, a time schedule based on observation and experience can be useful. If coordinated with frequent soil moisture inspections, it can work, but it really is a poor substitute for proper observation and instrumentation.

The thermocouple psychrometer can be used to measure soil and plant water potential. It is very accurate when properly used, but is extremely sensitive to a number of variables. Consequently, routine field use is not recommended.

Neutron probes are used to determine soil water content by measuring the degree of deflection of neutrons from a radioactive source by water in the soil. They are accurate, but are expensive, cumbersome, and require highly trained and licensed personnel to operate. They are generally not practical for tree nursery use.

Recommended Methods

Bare-Root Nurseries

Visual and tactile subjective observations and interpretations of soil moisture conditions are the most commonly used monitoring method. While there is no substitute for personal observation and judgement based on experience in nursery operations, every nursery should use some kind of quantifiable method indicating available water in the soil or plant internal stress. Tensiometers are the best instruments for measuring soil moisture at tree nurseries. They cover the critical 0 to -0.8 bar tension range, or most of the water that is readily available to the seedlings. The pressure chamber should be used at every nursery, because it is the only method giving direct readings of internal plant moisture stress.

Container Nurseries

In container nurseries, the weighing method is a good choice to supplement visual and tactile observations while the trees are small when used in conjunction with a soil moisture curve. After the trees become larger, a switch to the pressure bomb is suggested. The pressure bomb correlation method described next can be used in greenhouse situations as well as in conventional nurseries.

Relating Pressure Chamber Readings to Seedling Water Needs

The pressure bomb is the best field tool for plant moisture stress monitoring. To use it effectively, however, the readings acquired must be interpreted to provide indication of need for irrigation. Diurnal pressure bomb reading curves were discussed earlier for a species at a given nursery (fig. 3). Such curves will show a progressively more negative plant water potential as available soil moisture declines. We suggest charting the midday pressure bomb readings for a group of tree seedlings as they dry out, providing a curve relating available soil water to midday plant water potential (fig. 8). Note that at high soil moisture availabilities, plant water potential is highly influenced by humidity of the air at the leaf surface. Midday water potential curves can be broken into segments representing different levels of plant water stress. For this illustration, the curve segments are designated "adequate," "stressed," and "dangerous." The "adequate" segment reflects water stress developed solely by evaporative demand. Watering seedlings is unnecessary—adequate soil water is available.

The "stressed" segment is where plant water stress increases as soil moisture is depleted. The influence of soil water tension gradually overwhelms the effect of air humidity.

The "dangerous" segment is where, despite total stomatal closure, the seedling is still coming under increasing water stress. If the trees are not irrigated, irreversible damage can occur.

A primary problem in interpreting midday water potentials occurs along lines A-B and B-C. Note that from A to B the soil moisture is the same, but plant water potential can be different as a result of differing evaporative demands. Conversely, along line B-C the plant water potential is the same despite differing soil water tensions, again because of differing evaporative demand. Each nurseryman will have to determine where the midday water potential curve is for a given humidity or humidity band by accumulating data points at known humidities and then plotting the needed curves. This problem is simplified in greenhouses where humidities are more uniform.

Where internal plant stress is intentionally induced to stimulate root growth or to induce apical dormancy, the midday water potential curve can provide quantitative guides to the degree of plant water stress that is safe.

Development of midday water potential curves requires patient collection of data points over a period of time, and at different humidities, to generate accurate and reliable curves. Local research scientists with pressure bomb experience may be able to contribute helpful advice and data. The effort is

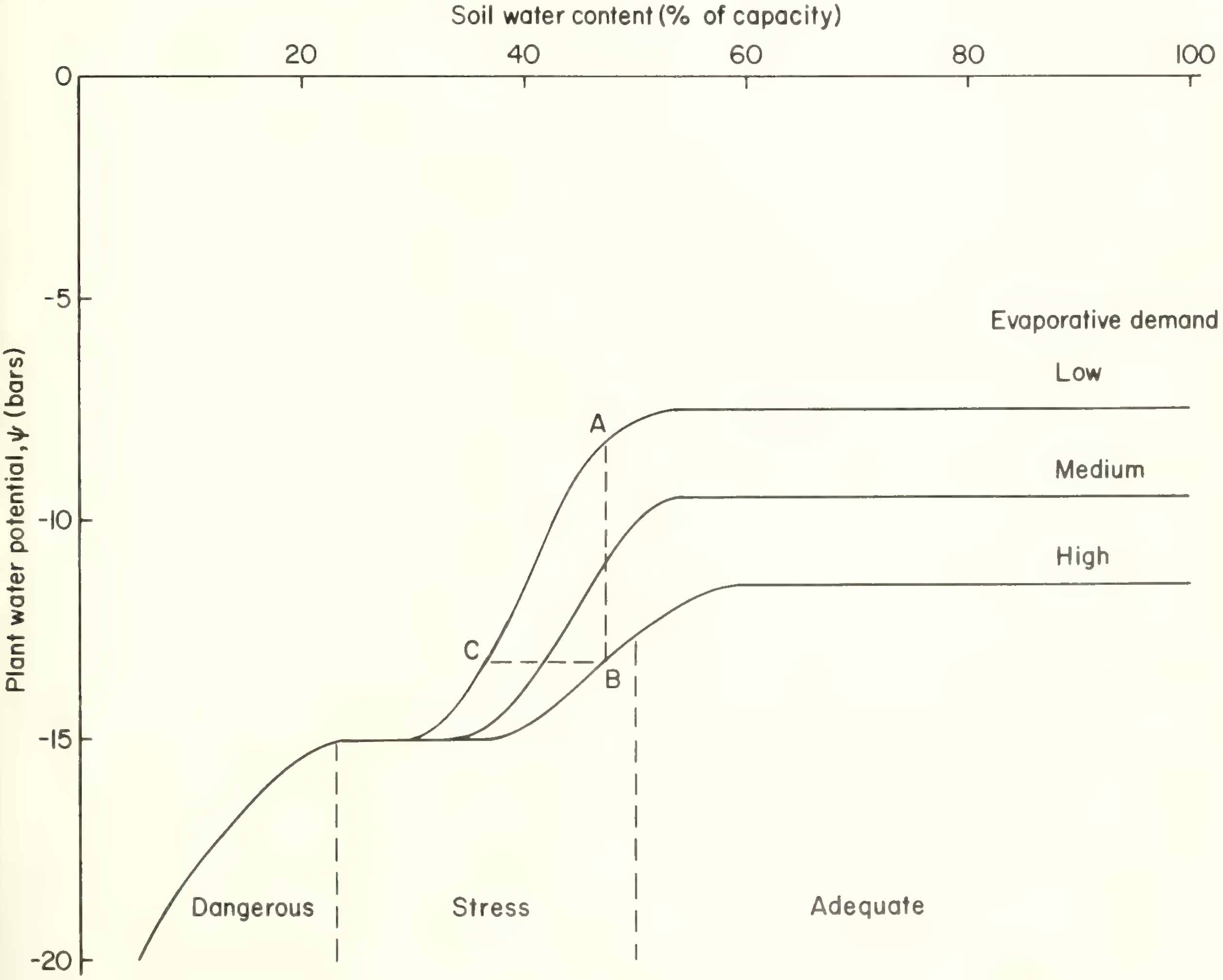


Figure 8.—The change in midday plant water potential produced by changing soil water content and different levels of evaporative demand.

worthwhile, for once a nursery has experience in pressure bomb work, the managers will have a direct, reliable, rapid, and inexpensive measure of seedling moisture stress to base their operational decisions on. The manager can also monitor the water stress condition of lifted and stored seedlings prior to outplanting. After outplanting, internal moisture stress of seedlings can be followed closely using the pressure bomb.

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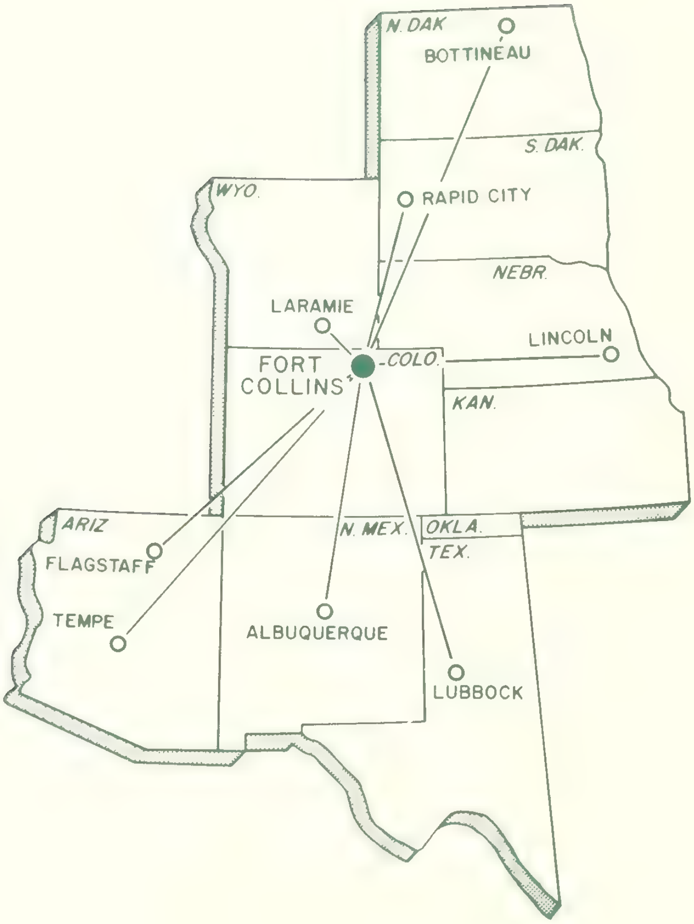
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Predicting Impact of a Restoration Project on River Dynamics: A Case History

Burchard H. Heede

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General Technical Report RM-62
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture

Abstract

Frequently forest hydrologists neither possess hard-core information for impact evaluations of restoration projects nor the time to gain this information. The report demonstrates how theory and experience gained elsewhere can be applied in such situations.

Keywords: Channel dynamics, aggradation, degradation, armoring, Salmon River.

General Technical Report RM-62 June 1979

Predicting Impact of a Restoration Project on River Dynamics: A Case History

Burchard H. Heede, Principal Hydraulic Engineer
Rocky Mountain Forest and Range Experiment Station[1]

The Land Manager's Dilemma

Interactions exist between streams and their environment (Shen 1972). In small streams the interaction may be so strong vegetation such as forests influences bedload movement and slope adjust processes (Heede 1972). Land management practices can, therefore, affect, and sometimes control, stream hydraulics. Projects dealing with watershed restoration (erosion control) may have severe influences because water and sediment delivery can be greatly changed in volume as well as lag time. The degree of influence not only depends on the type of stream environment but also on the condition of the stream itself, for example, aggrading or degrading channels, stream systems within or outside of dynamic equilibrium, and availability of large grain sizes and their distribution in the bed. Data are required to project and quantify expected management influences. Generally, for land (watershed) data such as climate, soils, geology, and vegetation are at hand; but for streams the required data are seldom available. These would include information on suspended and bedload transport, bed material sizes, stream competency, including dynamic equilibrium condition, and channel geometry. In addition, records on flow rates and other flow characteristics are needed.

The acquisition of missing data takes time. Usually this is not available due to pressing problems. Without hard-core data, projection equations (quantifications) cannot be developed. For such cases, the author suggests using available theory and experiences gained elsewhere to project the general direction of future stream developments as influenced by a given practice. This knowledge will be helpful in making management decisions.

The objective of this report is to demonstrate a historical case for which essential data were missing but project execution could not be postponed. Although a specific situation will be described, the approach, using theory and experience in combination with some existing data, can serve as an example for evaluations required under different circumstances. The reader is urged to recognize the great importance of apparent mechanics and dynamics of the river system for predicting the degree of influence of a proposed restoration project.

The Scope

Evaluations of critical stream locations must consider the stream as a whole, because many interactions exist between the different stream reaches and their dominant hydraulic variables. Streams are dynamic systems with a built-in tendency for adjustment to change (Heede 1975). Dump Creek's junction with the Salmon River represents a critical location because of past treatment and future developments. Changes at this junction may influence both downstream and upstream reaches. The junction could also be influenced by changes in upstream or downstream reaches independent of developments at Dump Creek.

During the last quarter of the 19th century, mining was big business in the Salmon River Mountains, and some of this activity was concentrated in the headwaters of a drainage later known as Dump Creek. Dredging and other placering operations were used for mining. The Dump Creek watershed has an extremely diversified geology, ranging from sedimentary materials, partially of volcanic origin, to igneous rocks (granites and basalts). Much of the soil parent material was granitic glacial till leading to formation of predominantly sandy soils. Typical of tills, intercalated lenses of sand and gravel are

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[1] Central headquarters maintained at Fort Collins, in cooperation with Colorado State University. Author is at the Station's Research Work Unit at Tempe, in cooperation with Arizona State University.

common and mostly of local extent. Although surface disturbances by mining operations brought subsurface gravel and boulders to the surface, the greatest detrimental impact was produced when Moose Creek was apparently diverted into the present Dump Creek. This diversion shortened the watercourse length and thereby increased bed gradients and flow velocities considerably. This produced a deep gully having widths reaching 400 feet (figs. 1 and 2). Project planners estimate the annual sediment yield of Dump Creek reaches 30,000 to 40,000 cubic yards. Based on the geology of the raw valley sides, it is estimated about 90% of this load is suspended sediment (sand sizes and smaller), and 10% bedload (particle sizes predominantly larger than sand size). This relationship was also found in the Salmon River headwater drainage by Emmett (1975) at Challis, Idaho (80 miles upstream from the Dump Creek junction).

Part of the coarse bedload from the Dump Creek drainage formed an alluvial fan at the creek's mouth. However, practically all the suspended load was transported downstream by the Salmon. The growing fan forced the Salmon River to undercut the Salmon River road (fig. 3). This road serves local residents, log transportation, and other land management activities downstream from North Fork.

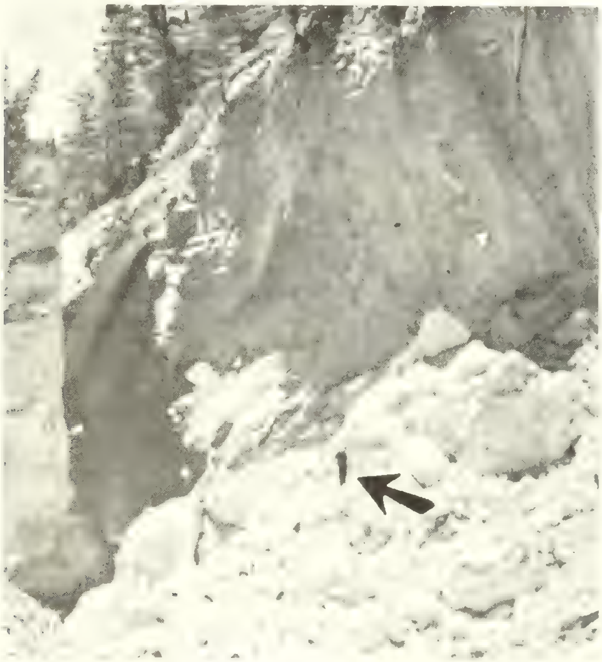

Figure 1.—Upstream view of upper reach of Dump Creek that developed into an immense-sized gully. Arrow points to a man standing on debris at right gully side slope.

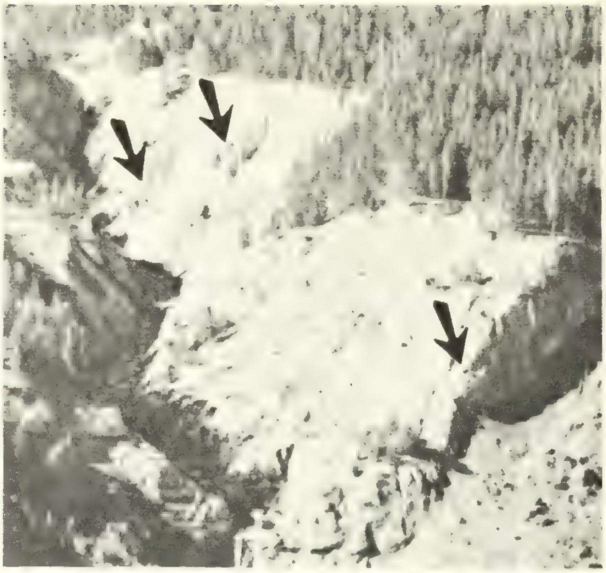

Figure 2.—Upstream view of lower reach of Dump Creek depicting the immensity of gully growth. Arrows point to volcanic plugs and dikes excavated by gully erosion.

The tendency for riverbed aggradation below the Dump Creek junction is indicated by long-term aerial photo observations, bar formations, frequency of bar overflows, and braiding tendencies of the river.

Planned Project

Objectives of the Dump Creek Restoration Project are to reduce the large amounts of sediment entering the Salmon River, to prevent future undercutting of the river road at the place of junction, and to introduce erosion control measures in and alongside Dump Creek. Forest administration had considered several alternatives and decided the objectives could be accomplished best with least amount of funds by diverting the flow back into Moose Creek. This will decrease flows into Dump Creek to a fraction of pre-project volumes thus reducing sediment transport.

Present Characteristics of the Salmon River

Emmett (1975) showed sedimentation is large in the Salmon River above the Dump Creek junction. Average annual sediment yield at Challis was estimated to be 2.5 million cubic yards. Dump Creek transports only 1.2 to 1.7% of this amount. The 5-mile reach between North Fork and Dump Creek, known as Deadwater, is of special interest to this study because it directly influences developments at the Dump Creek junction. As the name implies, the water flows very sluggishly through the Deadwater reach (fig 3), and compared to adjacent upstream reaches, its carrying capacity for sediment is very low. The average channel gradient through Deadwater is 0.00088 ft/ft (or 0.088%), which represents 33% of the reach gradient above Deadwater and 7.4% of the reach below Deadwater, located between Dump Creek and Moose Creek junctions.

Aerial photographs, taken at intervals up to 31 years, covered the peak flow period in 1974 when the largest flood on record occurred. They show a channel control exists on the upstream side of the alluvial Dump Creek fan. This control is signified by an abrupt change of flow regime: still water upstream (also at high water stages), and shooting flows below along the alluvial fan (fig. 3).

Could the fan itself be a control? Apparently this was assumed by the Corps of Engineers when they started artificially trenching the alluvial fan in 1962. Of an estimated 90,000 cubic yards, 12,000 yards were excavated. The next spring flow of Dump Creek buried the excavation again, and the project was abandoned. Corps records on this project are not available.

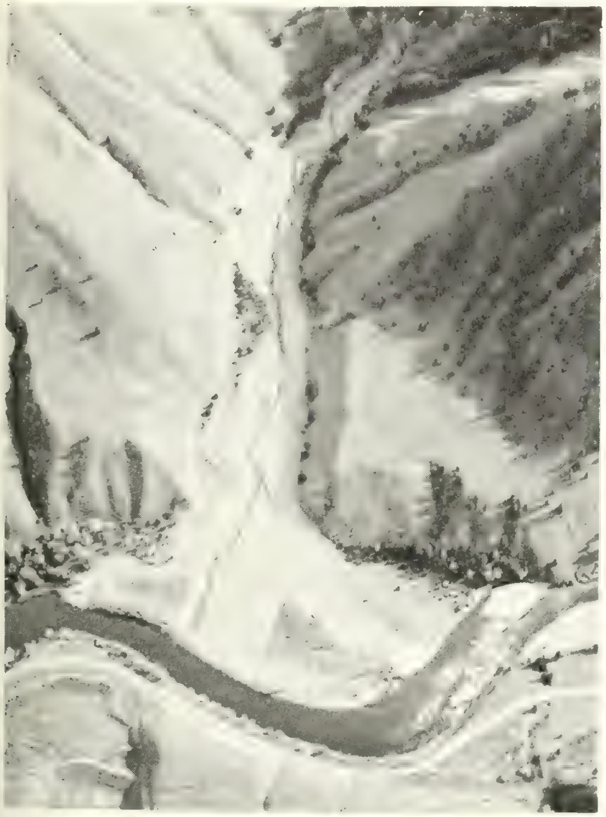

Figure 3.—The Dump Creek sediment fan at junction with Salmon River. Flow is from left to right. Note the still water surface upstream from junction in contrast to rapids downstream.

Strong geologic and hydraulic evidence as well as theoretical considerations indicate the fan itself was partly produced by the Salmon River channel control. Aerial photographs indicate lineal geologic-stratigraphic features are aligned with the flow regime breaking point. Before this investigation was conducted, Forest Service professionals proposed a volcanic dike existed at the control site. Indeed, the slumped valley side slopes of Dump Creek exhibit buried volcanic landforms such as plugs and dikes (fig. 2). Yet, it is also possible another geologic feature such as a disconformity (created by a fault, etc.) is responsible for this control.

Hydraulically, it is amazing that in spite of exceptionally large flows the fan perimeter at the mouth of Dump Creek changed only a minor amount over the years. This astounding fact was true for the upstream part of the fan which remained practically untouched during a record flood in 1974 when peak flow of the Salmon River exceeded that of Dump Creek by a factor of more than 25. This flood was the largest on record, and it was estimated to have a recurrence interval of 80 years. At this interval a high peak flow estimate by the Forest was 600 cfs for Dump Creek. The second highest peak flow on record for Salmon River was 16,500 cfs at Salmon (USGS 1965). The overriding magnitude of Salmon's flow should have altered the alluvial fan considerably. That it didn't indicates existence of an effective bed control.

The 13-mile reach downstream from Dump Creek to Spring Creek junction reflects sediment delivery by Dump Creek (fig. 4). Four larger bars, comprising areas of more than 2 acres, exist in this reach (fig. 5). These bars are frequently moving. Compared with reaches upstream from Dump Creek, bar frequency is much smaller downstream.

Aggradation in the channel reach is combined with overtopping of bars by high flows forming newly incised channels. Thus, braiding patterns occur. At other times heavy, sediment laden, rising-stage flows plug channels with deposits; and the less sediment laden recession flows cut new channels resulting in a shifting flow pattern (fig. 6). Two of the larger point bars, essentially part of the flood plain, are in private ownership and are used for agricultural production (mainly hay).

Below Spring Creek the valley bottom narrows producing greater flow depths and higher velocities (fig. 7). Bars are practically absent in the reach terminating at the Pine Creek bridge, approximately

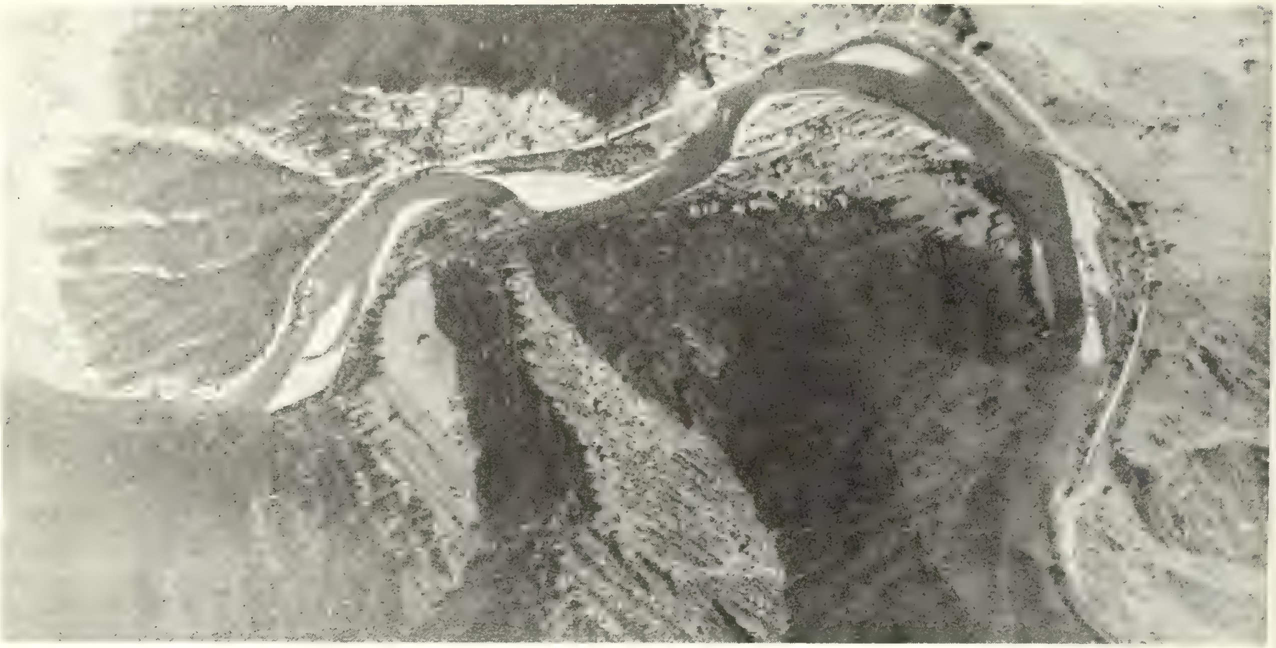

Figure 4.—The Salmon River downstream from the Dump Creek fan. Bar formations indicate high sediment loads. Flow is from left to right.

5 river miles downstream from Spring Creek. The valley becomes V-shaped and the river is geologically controlled by closely-spaced rapids for at least 6 miles (fig. 8). The investigations stopped at the rapids because they are effective as a present and future control. Regardless of future flow and sediment discharges only small changes will occur at this location (measurable only on a geologic time scale). The Lewis and Clark Expedition encountered this same control on August 24, 1805, and decided to discontinue river travel (DeVoto 1953). Today's name of this reach is the "River of No Return."

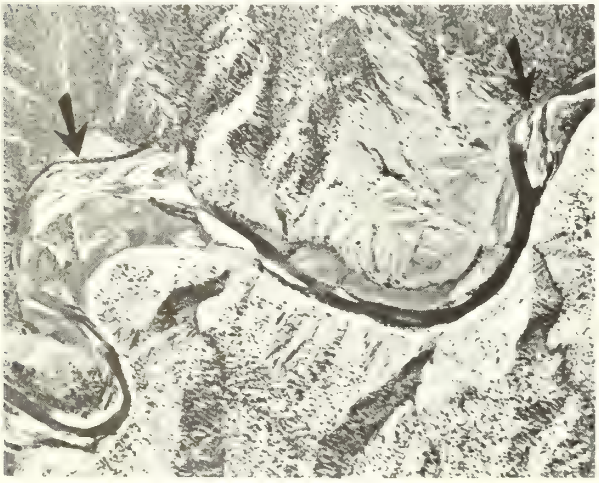

Figure 5.—Two of the larger point bars (arrows) existing in the 13-mile-reach downstream from the Dump Creek fan. The bar at left of figure has agricultural use, but is not free from inundations.

Expected Impact from Project

The preceding discussion demonstrates the dominant dynamics of the Salmon River in the reaches adjacent to Dump Creek. Following project initiation, Dump Creek's water discharge and sediment delivery should be decreased to about one-tenth of its present rate. With the smaller flows the average particle size (mainly of the bedload) will be much smaller than in the past. On the other hand, large quantities of easily transported sediment will continue to be produced from the raw valley side slopes, still much steeper than their angle of repose. Thus, suspended load and bedload will continue to be deposited into Salmon River but at a much slower rate than at present.

It is suspected that during the first years after project initiation, Moose Creek's washload (silt and clays, mainly) will offset some of the losses of suspended load. Unfortunately, even point data on Dump Creek's water and sediment yields are not available. Moose Creek's descent from the mountains to Salmon River follows a well armored channel bed (fig. 9). This is characterized by several locations of extreme bed roughness produced by

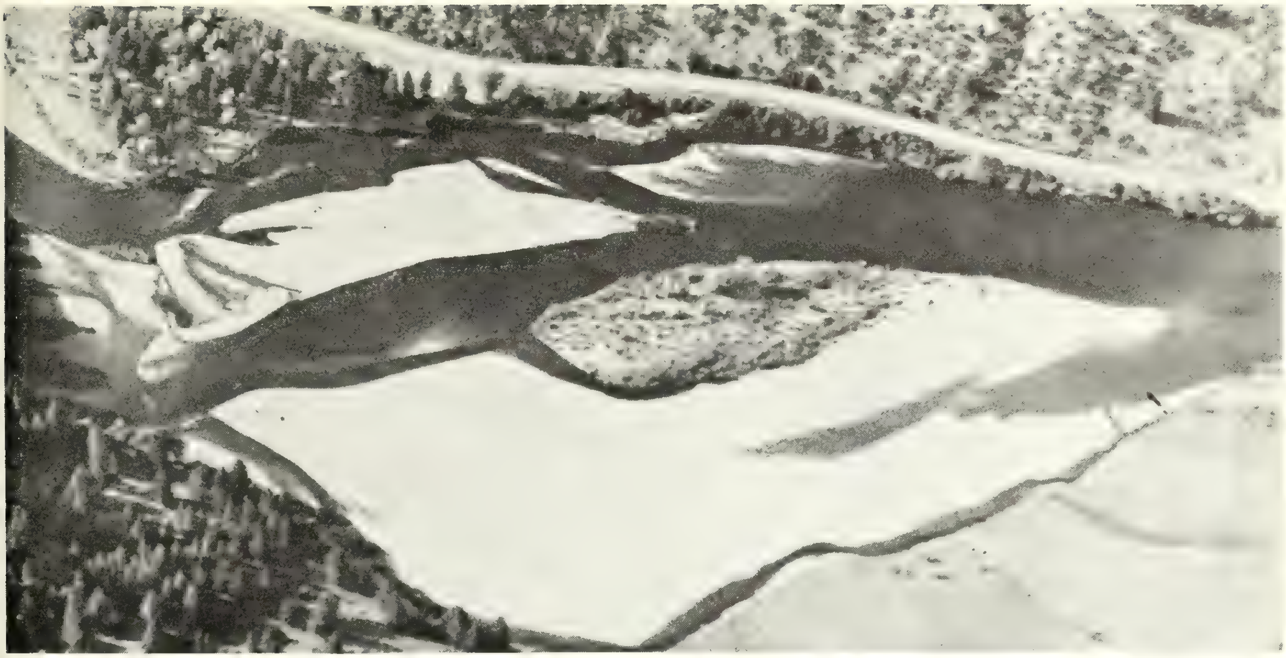

Figure 6.—This bar indicates the shifting flow patterns as influenced by low, high, and exceptionally high flows.

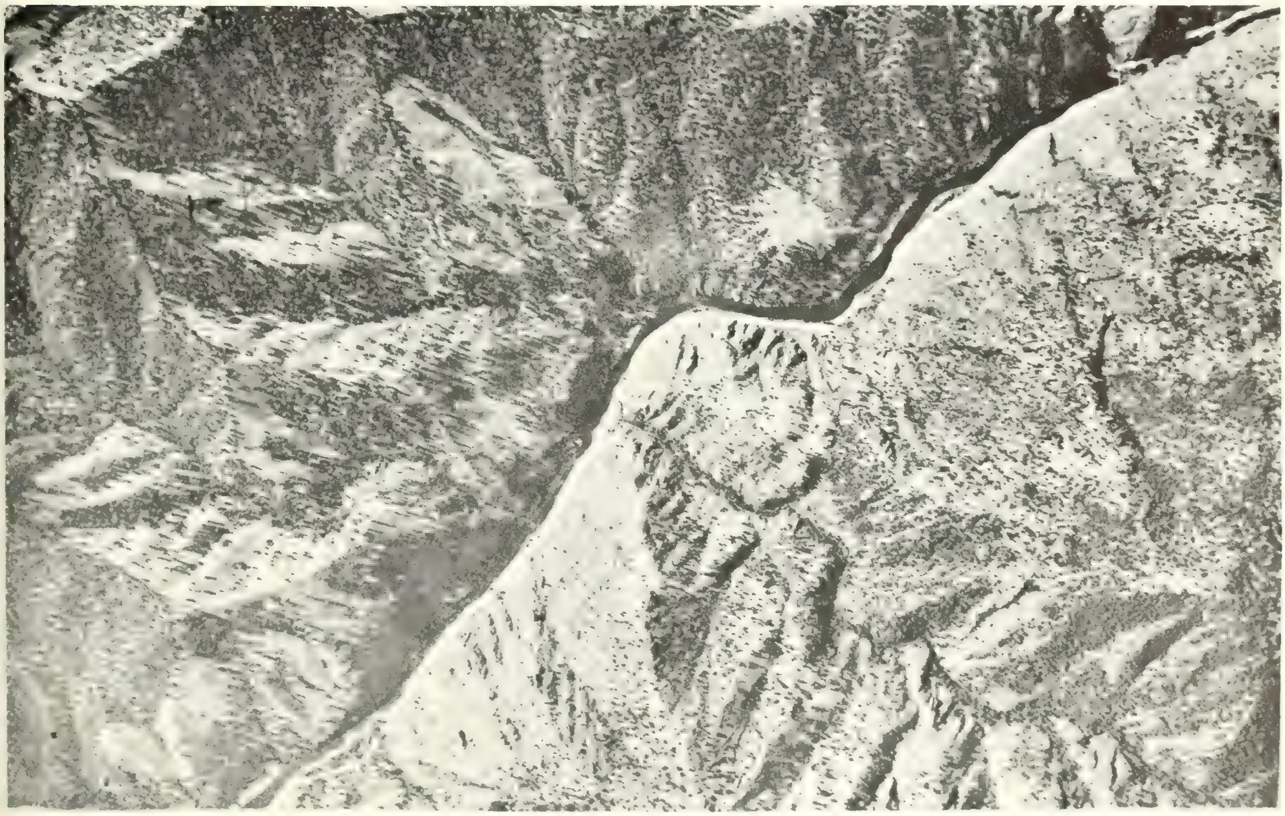

Figure 7.—In contrast to the reach illustrated in figures 4 and 5, lateral stream movement (adjustment) is not possible in this reach. Flow velocities are high and major bars absent. Practically all sediment is carried through this section.

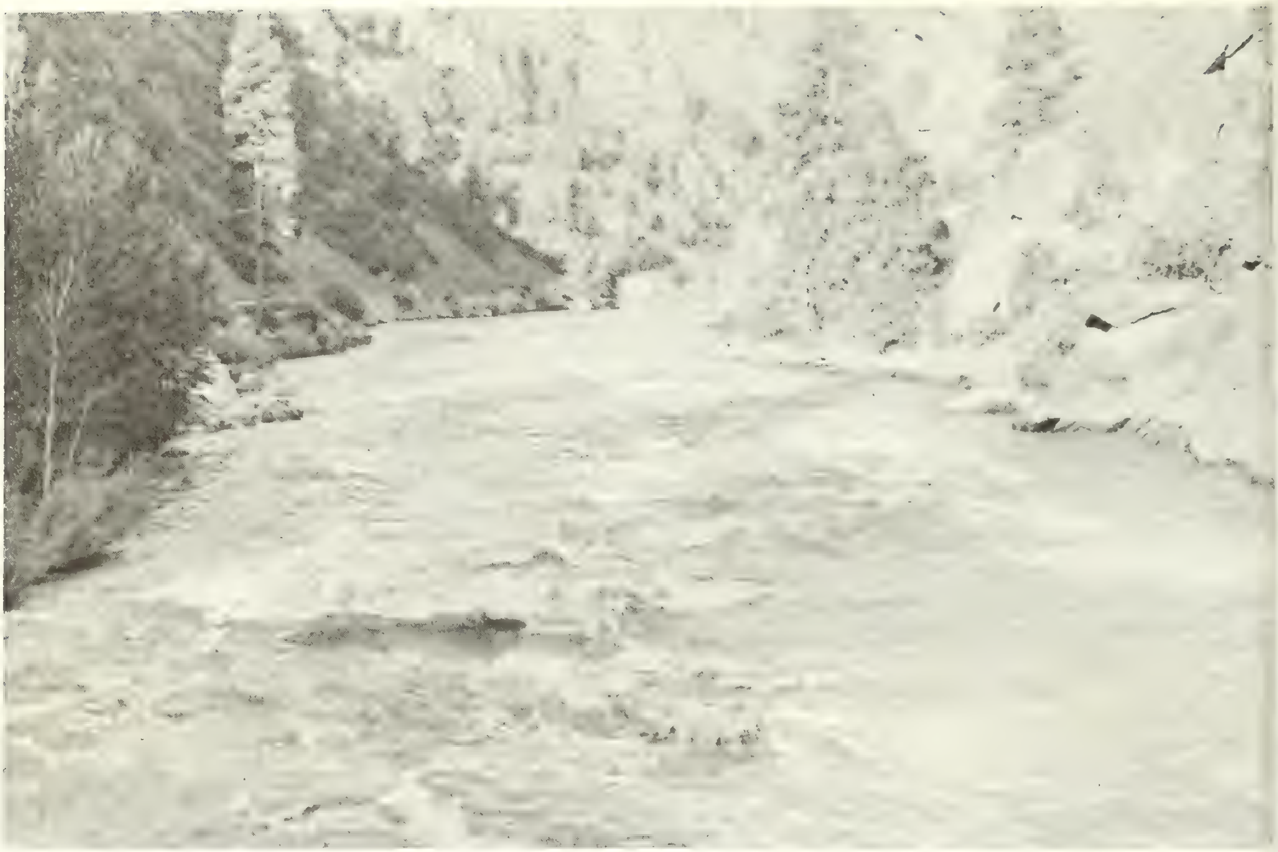

Figure 8.—Where the Salmon River narrows between steep mountain slopes, surface water waves indicate bedrock controls (rapids) on the river bed.

room-size boulders that break flow velocities and, if available, prevent delivery of coarse materials. Therefore, our concern must be centered on Dump Creek's influence on the Salmon.

Two expected changes in sediment delivery by Dump Creek of concern are (1) a decrease in sediment load, and (2) a decrease in average particle size of the load (Maddock 1973). The drastic decrease in sediment load will force the Salmon River to adjust its bed slope to a lower gradient. As well known from other rivers (e.g. River Rhine and Colorado River), where the load has been manipulated by man, adjustment leads to degradation in the reach downstream from the point of sediment withdrawal (or reduction) and to aggradation of the excavated material farther downstream (Borland and Miller 1960). On the Colorado River, where practically all sediment was withdrawn by Hoover Dam (about 160 million tons annually), the stream degraded a maximum of 15 feet in 14 years. Adjustment still proceeds by lateral movements, mainly taking out bars not sufficiently armored (Gessler 1971). Such bed cuttings have a wedge-shaped longitudinal profile with the deepest cut at the point of sediment withdrawal.

The sediment discharge of Colorado River was 800 times greater than the Salmon at Challis, 80 river miles upstream from Dump Creek. Although data are not available to calculate depth of cuttings in Salmon River, past predictions by experts in the field show an accuracy of only one order of magnitude, for example, River Nile below Aswan Dam (Hammad 1972). Since the Colorado River project totally removed all sediment, the impact would be more severe than would be expected by the Dump Creek Project. A conservative estimate, based on Colorado River data, would be a maximum bed lowering of 1 to 1.5 feet at Dump Creek. The cut would not be expected to reach Pine Creek bridge, about 18 river miles downstream from Dump Creek. Thus, the bridge buttresses, armored by heavy boulders, will not be affected. Indeed, some aggradation may take place upstream from the bridge where relatively minute point and cross-over bars may be enlarged. Maximum aggradation of less than 1 foot is expected since most of the material excavated below Dump Creek junction will be carried through the confined channel reach into the rapids downstream from the bridge.

Where valley bottoms are wide, slope adjustment will take place by lateral stream movements (Neill 1971, Heede 1977). At present, four flood plains exist that developed from point bars and now support a braided flow pattern. Here, the original meander may be reestablished by lateral movement. But, again, changes will be relatively small, not exceeding a few feet.

In conjunction with deep bed cutting, changes in the channel gravel-boulder armor will most likely occur. This will occur because of a decrease in the average particle size of the load. Several investigators (Gessler 1965, Little and Mayer 1976) have shown streams conveying water through alluvium tend to be armored with the larger particle sized material. However, we should recognize the top layer of the bed is made up predominantly of these larger sizes and also contains the same smaller grains present in the underlying layer. During the armoring process, sorting occurs and the finer fractions are eroded away leaving the larger particle sizes concentrated in the top layer, although there is no distinct boundary between the erodable and non-erodable grain size. When the sediment source and flow magnitudes are altered, the armor layer is changed. When this armor layer is changed, new bed levels develop parallel to the original bed level.

In our case, Dump Creek will decrease its estimated volume of water by nine-tenths. The process resulting from this change can be visualized as follows: the larger particles that presently make up the bed will not be replenished by Dump Creek. Since much smaller sizes will be deposited, flows in the Salmon River will pick up more of these deposits than before the project. In addition, selective transport of smaller grain sizes available in the top layer continues in the bed of the Salmon River. The combined effect will be a lowering of bed level in the upstream portion of the Salmon reach below the junction with Dump Creek. Thus, deep cutting will be caused by reducing both load and particle size. The maximum cutting below the junction is estimated to be about 2 feet. Cutting will proceed gradually, and little change in sediment will occur at the tributary junction because a sizeable amount of material is still available for transport downstream, and sediment delivery will not be fully stopped.

Changes in the bed level associated with alignment will be beneficial. At present, Dump Creek forces the Salmon River toward the road at the point of junction leading to bank undercutting. After project initiation, this bank can be safely protected by revetment with a minimum of effort because the effect of Dump Creek will be reduced. The flood plains below Dump Creek were frequently inundated in the past, causing damage to the private agricultural land. Consequently the owner expended much effort in the past to construct dikes to protect his land. Natural bed deep cutting should eliminate this need. Less sediment coming from Dump Creek will increase the ability of the Salmon River to transport sediment loads through the reach and over time will decrease (or eliminate) such problems as braiding, and flooding of low-lying lands.

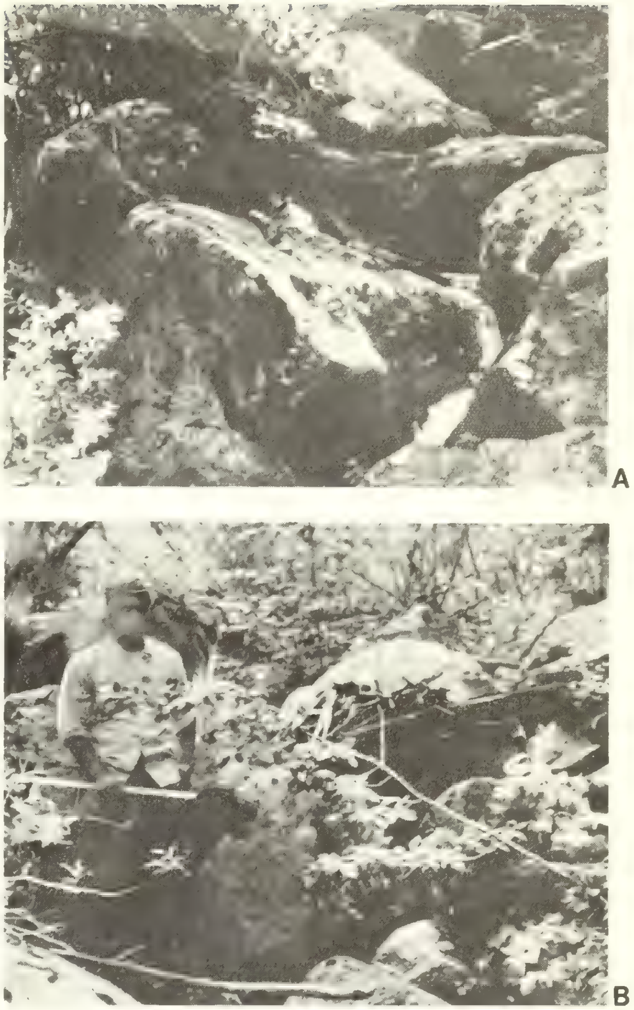

Figure 9.—The bed of Moose Creek is well armored on its descent from the mountains to the Salmon River. (A) Upstream view; (B) Man gives scale to the size of the bed armor material.

Some undesirable effects which may arise from the project are channel wanderings, until a new quasiequilibrium stream condition is established. These may result in cutting of outside meander banks but will only be of minor magnitude as compared to present-day conditions. If it should be judged necessary, much less effort will be required for bank protection work than training the presently aggrading reach.

There may be some aggrading in the reach between Spring Creek and Pine Creek, causing small-scale enlargements of present small point and cross-over bars. These changes will be hardly noticeable because the reach is generally well defined in a relatively narrow valley bottom.

Without hard-core data, it is difficult to estimate the time necessary for the Salmon River to adjust to post-project conditions. The rate of adjustment will depend on high flow frequencies and magnitudes. Using Colorado River as a benchmark, it is believed the Salmon River will require 5-10 years to adjust to project changes.

The evaluation of the project's impact on the Salmon River below the "River of No Return" was not attempted because the water and sediment from Dump Creek made up only a minute amount of this total.

It is recommended, if the project is done, post-treatment behavior of Salmon River be monitored in the reaches below Dump Creek and Moose Creek as well as Dump Creek and Moose Creek in order to test the model predictions. Furthermore, such tests will increase information on stream dynamics. Too often this prediction aspect is omitted and with this the opportunity to strengthen our knowledge.

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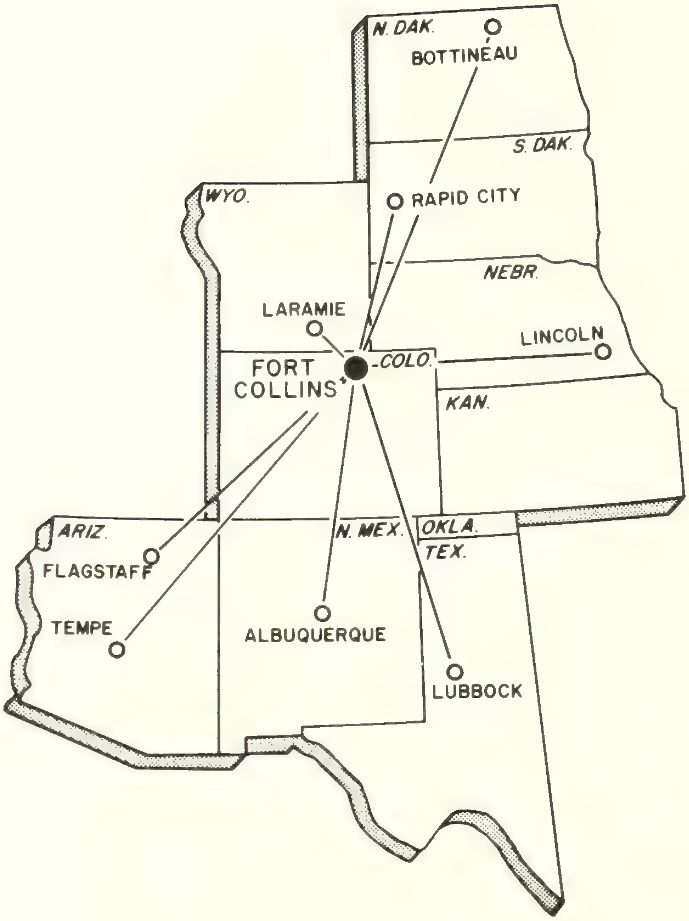
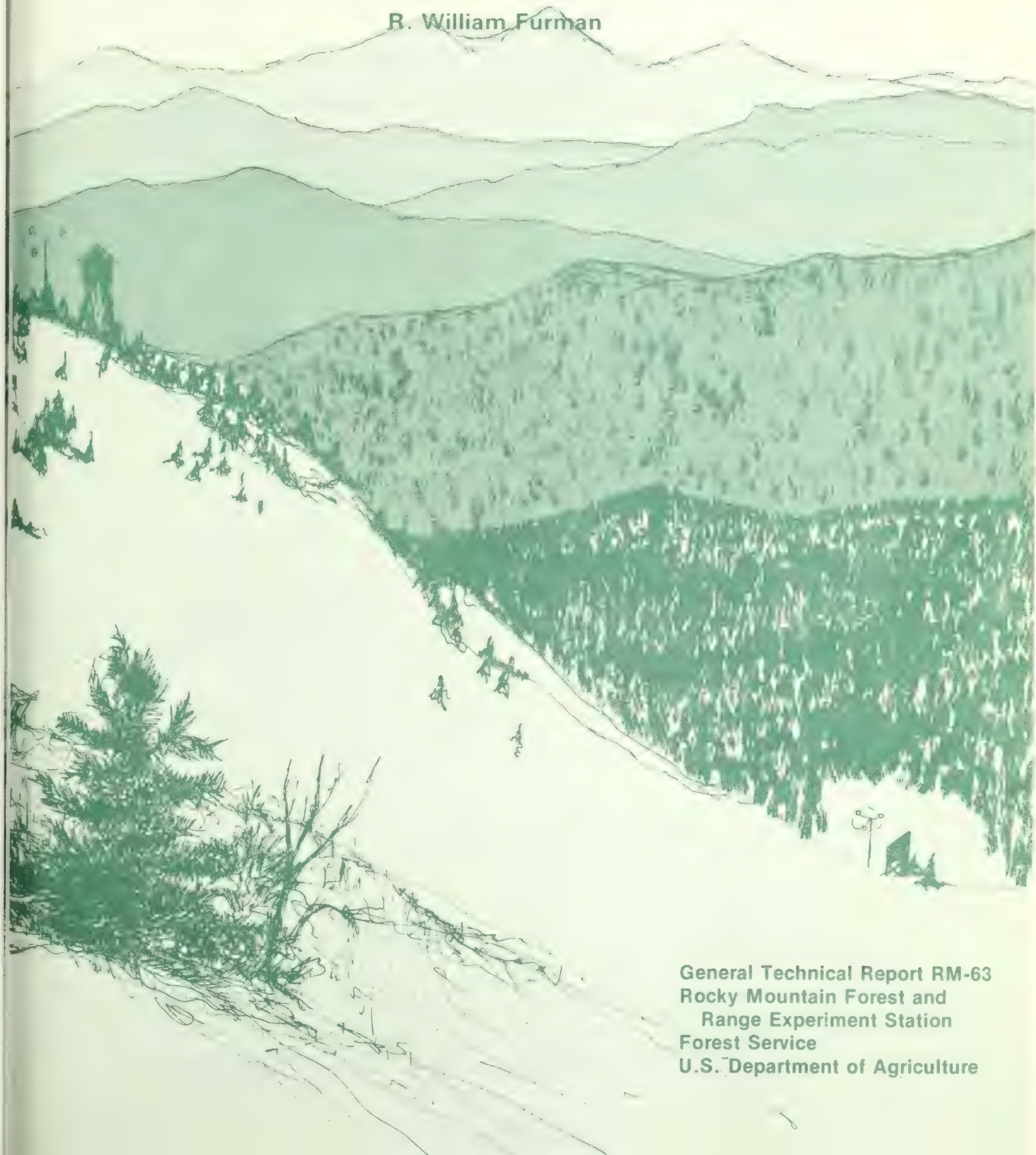

N. DAK.
BOTTINEAU
S. DAK.
WYO.
RAPID CITY
NEBR.
LARAMIE
LINCOLN
FORT COLLINS
COLO.
KAN.
ARIZ.
N. MEX.
OKLA.
TEX.
FLAGSTAFF
TEMPE
ALBUQUERQUE
LUBBOCK

Using Fire Weather Data in Prescribed Fire Planning: Two Computer Programs

R. William Furman



General Technical Report RM-63
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture

General Technical Report RM-63 June 1979

Using Fire Weather Data in Prescribed Fire Planning: Two Computer Programs

R. William Furman, Principal Meteorologist
Rocky Mountain Forest and Range Experiment Station[1]

Abstract

Local fire managers can use previous years' fire weather observations (including data from the National Fire Weather Library) to estimate probabilities of future days' falling within burning and smoke dispersal prescriptions. The computer programs can be used by field personnel from remote terminals via telephone service.

Keywords: Prescribed fire, fire use planning, climatology, computer program.

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[1] *Central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Using Fire Weather Data in Prescribed Fire Planning: Two Computer Programs

R. William Furman

MANAGEMENT IMPLICATIONS

Although fire behavior and fire danger are to a large part determined by the past and present weather, fire use planners have often lacked access to or failed to use climatological information as a planning tool. The current emphasis on more professional fire management policy will produce increased use of climatological information in future fire use planning.

A prognosis of what the weather may be 6 months to a year in the future can be obtained by determining the frequency with which events happened in the past. Historic weather records reveal patterns which can be used by fire planners to designate preferred seasons for prescribed burning and to help establish a reasonable target for a burning program.

INTRODUCTION

How many days a year can be expected to satisfy the prescribed weather conditions for a specific planned burning operation?

During what parts of the year are favorable prescribed burning conditions most likely to occur?

Do favorable burning days occur together in groups of 2, 3, or more contiguous days or are single occurrences of burning days more likely?

What amount of persistence is characteristic of the weather conditions in a region? In other words, if today is a burning day, what are the chances that tomorrow will be one?

How will the expected number of burning days per year be affected if smoke management restrictions are added to the prescription?

The planner may reasonably ask these questions in trying to find the best method for using fire to accomplish specific objectives. Reliable answers to these questions enable the planner to reduce the uncertainty of predicting the occurrence of the number of days meeting his fire prescription. The planner may base the choice of method on the conditions expected. For example, if one can expect 30 days a year acceptable for slash disposal, then the plan may be to dispose of 1/30 of the total amount of slash on each disposal day. That way the desired outcome of disposing all the slash will, in the long run, be achieved.

In the normal course of planning, fire management must be concerned with weather as much as a year or more in the future. However, the state of our technology does not permit an accurate weather forecast much beyond 3 days. Another source of future weather information must be used—climatology. Climatology substitutes weather hindsight for weather foresight by assuming climate in the near future will be similar to the climate of the recent past, say in the past 2 or 3 decades. We cannot determine which specific weather occurrences from the past will be repeated at any given time in the future. Instead, we examine all of the past occurrences and assume they will occur with the same frequency in the future. For example, if our data sample is large enough we may reasonably expect half of the future years will experience more days in prescription than the median number of prescription days per year experienced during the past years.

WEATHER INPUTS TO FIRE USE PLANNING

Two items are basic to a climatology of prescribed weather conditions—a weather data base and a prescription.

Data Base

The data base most fire managers will be using is the fire weather records obtained from the fire weather stations in their management unit. Fire weather data are taken for and used in assessing daily fire danger on a protection unit. They may be observations taken by the fire management agencies for the explicit purpose of determining fire danger, or they may be taken by the National Weather Service and used by the fire managers.

Typically in a fire weather observation, the measured variables include state of the weather, dry bulb temperature, relative humidity, windspeed and direction, moisture of 1/2-inch pine dowel array (fuel sticks), precipitation, and sometimes maximum and minimum temperatures and humidities. These data are normally accessible through the National Fire Weather Data Library (Gen. Tech. Rep. RM-19, Furman and Brink 1975). This data library is a user-oriented data management system established on the USDA computer system in Fort Collins, Colo. From remote terminals via telephone service, users may create their own data file of selected information using available software. This data library is kept up to date with the observations used to compute daily fire danger across the nation.

Prescription

The prescription is a translation of the fire manager's treatment objectives, such as scorch height and flame length, into weather and fuel conditions that will allow those objectives to be achieved. It is a set of conditions which must be satisfied before a decision should be made to execute a burn treatment. It is also used to define the environment for the proper fire to accomplish the treatment objectives. Specificially, it should consist of the minimum number of weather and weather-related variables necessary to restrict the fire behavior to the desired characteristics. All the conditions in a prescription must occur simultaneously for a prescription to be satisfied.

Using either too restrictive a prescription or an overly complex one is undesirable. Either will result in a decrease in the number of days predicted to be acceptable for burning. For example, requiring the 10-hour timelag fuel moisture to be 13-15% instead of 10-15% will severely restrict the number of acceptable days. Similarly, if a prescription is too complex, that is, if there are many more viariables than necessary, the chance of satisfying all the variables simultaneously is small. Fire managers should take a critical, professional look at their prescriptions and eliminate the variables that are only marginally applicable. This will increase the number of days available for using prescribed fire.

When the manager wants to limit burning to days meeting specific smoke dispersal patterns, an additional, specialized set of variables becomes part of the prescription. The dispersal of smoke depends upon the stability of the air layer above the smoke source and on the wind speed and direction in that layer. Therefore, estimation of smoke dispersion characteristics depends on measurements of properties in the layer of atmosphere above the area to be burned. These measurements are, of course, never actually taken. However, measurements from particularly situated fire weather stations can permit crude approximations of the data which would have been taken. For example, data from two fire-weather stations, one at a high elevation site (e.g., a lookout), the other at a low elevation site not too far from the high site (i.e., 30 to 40 miles), can be combined to obtain crude estimates of smoke dispersion characteristics.

Three properties of the air layer next to the earth surface strongly regulate the ability of the smoke column to rise an acceptable distance above the source and be carried away in a desirable direction—transport wind direction, transport windspeed, and atmospheric stability or instability.

Transport Wind Direction

It is reasonable to assume the wind direction at a well exposed lookout is representative of the wind direction in the nearby free atmosphere (Judson 1965) at that altitude. At any given instance this may not be true, but in the long run we can expect this assumption to hold within limits of ±22.5°. The lookout wind direction can thus be used as an indicator of the direction smoke will be transported. For most planning purposes no greater precision is needed.

Transport Windspeed

Finklin[2] reported a positive correlation between the afternoon windspeed at a mountaintop station and windspeed in the free atmosphere. Judson (1965) also reported a positive correlation between windspeed at a high elevation station and windspeed at the same altitude in the free atmosphere over Weather Service stations roughly 100 air miles away. The high elevation station windspeed consistently underestimated the free air speed. Thus, any error in using lookout windspeed to estimate smoke dispersion conditions aloft will probably be on the safe side.

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[2] *Finklin, Arnold I. 1977. Climate of the Selway-Bitterroot Wilderness. Office Report for Fire in Multiple Use Management Development and Application Program, USDA For. Serv., Intermt. For. and Range Exp. Stn., North. For. Fire Lab., Missoula, Mont. 260 p.*

Atmospheric Stability

The third property of air important in predicting smoke dispersal is atmospheric stability; the resistance of the atmosphere to vertical motion. The smoke-laden air from a fire will continue to rise through the surrounding air only as long as it is warmer than that air. If the air above the fire site is warmer than the rising smoke-laden air from the fire, the smoke will not rise; instead, it will sink to the valley floor. Schroeder and Buck (1970) contains a detailed and highly readable discussion of this property.

The tendency of the warm, smoke-laden air from a fire to rise through the air above the fire site can be determined by comparing the rate of cooling of the rising air to the changes in temperature in the air at increasing elevations above the fire site.

The change in temperature per 1,000 feet elevation of the air in a column over a point on the earth's surface is called the atmospheric lapse rate. To approximate this rate, divide the difference in temperature between the air at a high elevation station (e.g., a lookout) and the air at a neighboring low elevation station (e.g., one in a valley bottom), by the thousands of feet difference in elevation between the two sites (fig. 1, solid line).

The cooling of rising air is expressed as a theoretical constant rate: a parcel of air mechanically lifted and not allowed to mix with the surrounding atmosphere would cool, because of expansion, at a fixed rate of 5.4° F/1,000 feet of elevation as long as it remained unsaturated (fig. 1, dashed line). This rate is called the dry-adiabatic lapse rate.

If we subtract the dry-adiabatic lapse rate (5.4° F/1,000 ft.) from the atmospheric lapse rate (valley bottom temperature minus lookout temperature/1,000 ft.) and get a positive number, we will have good smoke dispersion. The bigger the difference, the better the dispersion. A negative difference means poor smoke dispersal conditions.

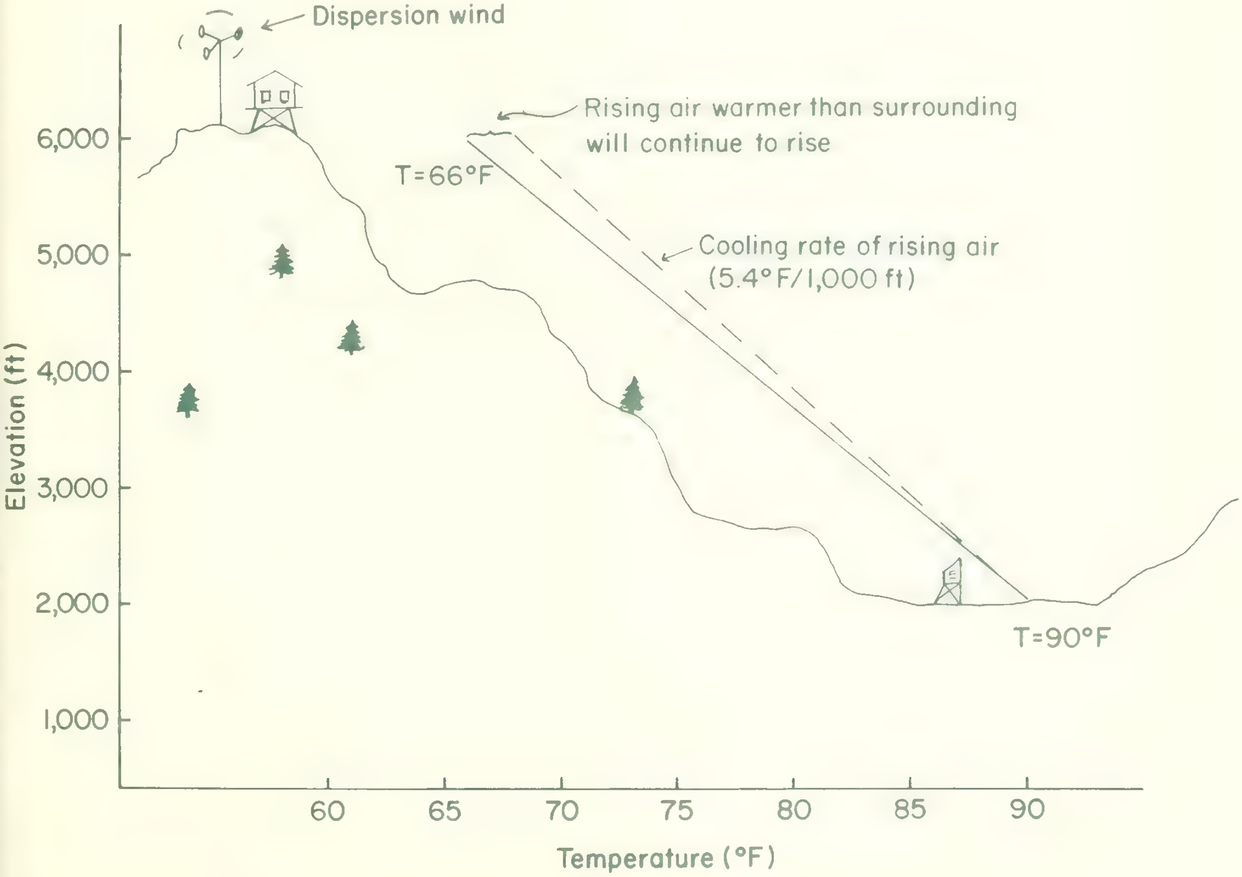


Figure 1.—A schematic of the atmospheric (solid) and adiabatic (dashed) lapse rates between high and low elevation stations.

COMPUTER PROGRAMS FOR FIRE PLANNING CLIMATOLOGY

Two computer programs have been developed and saved on the USDA computer at Fort Collins, Colo., as an aid to fire managers. These programs can be used separately or together to analyze pertinent weather data.

PRESCRB—A Climatology for Fire Use Planning

The computer program PRESCRB synthesizes weather data into a meaningful form for fire use planning. Program input includes a data base of meteorological observations and the user's burning season and prescription. The data base can be provided by the user or can be obtained from the National Fire Weather Data Library. The program counts the occurrences of days which had weather conditions satisfying all of the prescription variables and presents this information on the output in various formats.

Instructions to Execute PRESCRB

The runstream (a list of computer commands) in figure 2 provides the information necessary to build a data file of weather records from the National Fire Weather Data Library and execute PRESCRB. The flexibility of the program allows users to use meteorological data files other than the National Fire Weather Data Library (i.e., the output data file from program FIRDAT or any other set of data). Users not desiring to build the data-file can eliminate instructions 1 through 7. Executing this runstream will produce the output in figure 3.

An explanation of figure 2 is as follows:

1. Obtain exclusive use of the library program file.
2. Assign the *first* of the data files (tapes) from which the data are to be extracted. If more than one file is needed,they will be dynamically assigned and freed during execution. See Gen. Tech. Rep. RM-19 for instructions on how to obtain the current list of data files.

```
       1234567890123456789012345678901234567890

   1.  @ASG,AX FIREDATALIB*PRØGRAMS.

   2.  @ASG,A FIREDATALIB*45A-47.

   3.  @USE 2.,FIREDATALIB*45A-47.

   4.  @ASG,T 15.

   5.  @XQT FIREDATALIB*PRØGRAMS.GETDATA2

   6.    45250800  45250899

   7.  @FREE 2.

   8.  @ASG,AX CLIMATØLØGY*PRØGRAMS.

   9.  @XQT CLIMATØLØGY*PRØGRAMS.PRESCRB

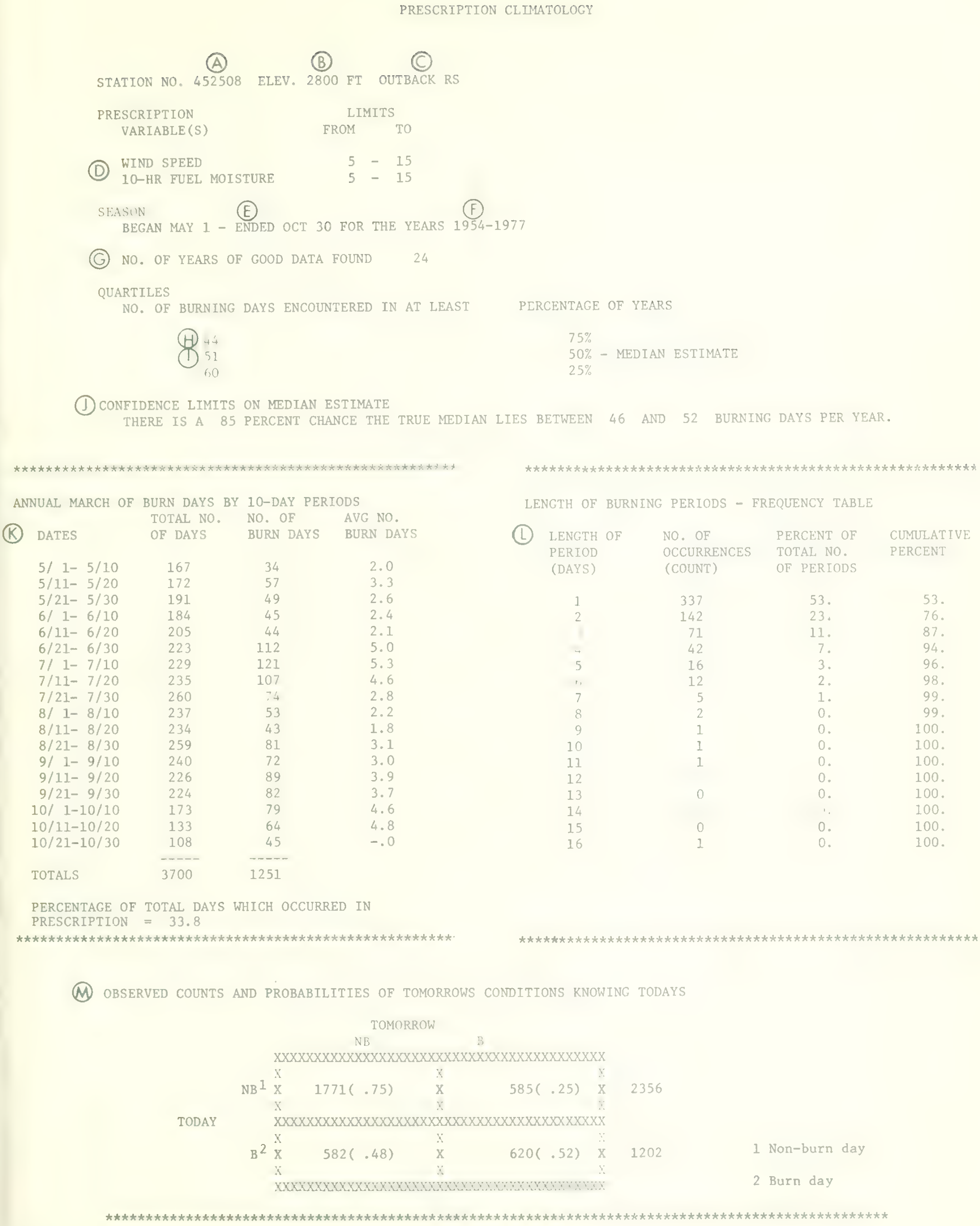
  10.  STATN 452508  2600  2   540501 771031 ØUTBACK RS

  11.  VARIBL  4  5 15WIND SPEED

  12.  VARIBL  5  5 1510-HR FUEL MØISTURE

  13.  @FIN
```

Figure 2.—Example runstream for obtaining output from program PRESCRB.



```
                              PRESCRIPTION CLIMATOLOGY

                 Ⓐ            Ⓑ           Ⓒ
     STATION NO. 452508  ELEV. 2800 FT  OUTBACK RS

     PRESCRIPTION                  LIMITS
        VARIABLE(S)              FROM     TO

   Ⓓ  WIND SPEED                  5  -   15
      10-HR FUEL MOISTURE         5  -   15

     SEASON          Ⓔ                            Ⓕ
        BEGAN MAY 1 - ENDED OCT 30 FOR THE YEARS 1954-1977

   Ⓖ  NO. OF YEARS OF GOOD DATA FOUND      24

     QUARTILES
        NO. OF BURNING DAYS ENCOUNTERED IN AT LEAST      PERCENTAGE OF YEARS

                Ⓗ 44                                            75%
                Ⓘ 51                                            50% - MEDIAN ESTIMATE
                  60                                            25%

   Ⓙ CONFIDENCE LIMITS ON MEDIAN ESTIMATE
        THERE IS A  85 PERCENT CHANCE THE TRUE MEDIAN LIES BETWEEN  46  AND  52  BURNING DAYS PER YEAR.

*****************************************************        *******************************************************

ANNUAL MARCH OF BURN DAYS BY 10-DAY PERIODS                  LENGTH OF BURNING PERIODS - FREQUENCY TABLE
                  TOTAL NO.    NO. OF      AVG NO.
Ⓚ  DATES          OF DAYS      BURN DAYS   BURN DAYS          Ⓛ  LENGTH OF     NO. OF        PERCENT OF    CUMULATIVE
                                                                 PERIOD        OCCURRENCES   TOTAL NO.     PERCENT
                                                                 (DAYS)        (COUNT)       OF PERIODS
   5/ 1- 5/10      167          34          2.0
   5/11- 5/20      172          57          3.3                    1             337           53.           53.
   5/21- 5/30      191          49          2.6                    2             142           23.           76.
   6/ 1- 6/10      184          45          2.4                    3              71           11.           87.
   6/11- 6/20      205          44          2.1                    4              42            7.           94.
   6/21- 6/30      223         112          5.0                    5              16            3.           96.
   7/ 1- 7/10      229         121          5.3                    6              12            2.           98.
   7/11- 7/20      235         107          4.6                    7               5            1.           99.
   7/21- 7/30      260          74          2.8                    8               2            0.           99.
   8/ 1- 8/10      237          53          2.2                    9               1            0.          100.
   8/11- 8/20      234          43          1.8                   10               1            0.          100.
   8/21- 8/30      259          81          3.1                   11               1            0.          100.
   9/ 1- 9/10      240          72          3.0                   12                            0.          100.
   9/11- 9/20      226          89          3.9                   13               0            0.          100.
   9/21- 9/30      224          82          3.7                   14                            0.          100.
  10/ 1-10/10      173          79          4.6                   15               0            0.          100.
  10/11-10/20      133          64          4.8                   16               1            0.          100.
  10/21-10/30      108          45          -.0
                  -----        -----
  TOTALS          3700         1251

  PERCENTAGE OF TOTAL DAYS WHICH OCCURRED IN
  PRESCRIPTION  =  33.8
*****************************************************        *******************************************************


   Ⓜ OBSERVED COUNTS AND PROBABILITIES OF TOMORROWS CONDITIONS KNOWING TODAYS

                                   TOMORROW
                                 NB              B
                        XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
                        X                  X                     X
                    NB¹ X    1771( .75)    X       585( .25)     X   2356
                        X                  X                     X
           TODAY        XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
                        X                  X                     X
                     B² X     582( .48)    X       620( .52)     X   1202            1 Non-burn day
                        X                  X                     X
                        XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX                  2 Burn day

      ***********************************************************************************************
```

Figure 3.—Output from program PRESCRB –a prescription climatology for a fictitious fire weather station, with inputs (A,B,C,D) and outputs (E,F,G,H,I,J,K,L,M).

3. Assign internal unit number 2 to the library data tape.
4. Assign a mass storage file to receive the card images. This is a temporary file and will disappear when the run terminates.
5. Execute the absolute element to select the data and write it on file 15.
6. Data cards specifying the beginning and ending station-year of the data cards to be extracted.
7. Release fire weather library data files.
8. Obtain exclusive use of the program file which includes PRESCRB.
9. Execute the absolute element to produce a prescription climatology. Input weather data is expected on file 15.

10., 11., and 12. Control data cards for PRESCRB.

13. Terminate run.

If it is known before the first execution that the program PRESCRB will be executed several times using the same weather records, weather data should be saved in a file on the first run to save the cost of recreating that file on subsequent runs. This may be done by substituting the following for instruction number 4:

```
4.  @ ASG,UP CARDS.
4a. @ USE 15., CARDS.
```

Then on subsequent runs, eliminate instructions 1-7 and substitute the following two instructions:

```
1. @ ASG,AX CARDS.
2. @ USE, 15., CARDS.
```

Depending on current facility policy, a file saved as above will be saved on the computer for a number of days, 6 days at this writing. To prevent being charged for saving a large data file on mass storage beyond its useful period, insert the following two instructions in front of the @ FIN card on the last execution of the program with that data set:

```
@FREE 15.
@DELETE CARDS.
```

Program Input

Input required for execution of PRESCRB is of two kinds, program data and weather data. The program data consists of a card on which is designated the fire weather station whose weather data is to be analyzed, the number of variables in the prescription, and the dates defining the season to be analyzed. The remaining cards in the program data deck are cards which define the variables and their limits as they make up the prescription. The weather data can be analyzed over and over again by repeating the program data deck. Following is a detailed description of the program data cards:

First data card—STATN—one card

Col. 1-5	STATN
Col. 7-12	Station number
Col. 14-18	Station elevation (right justified)
Col. 20-21	Number of variables in prescription—maximum of 10 (8 if relative humidity is used)
Col. 23	Number of variable format cards
Col. 25-26	First year of meteorological data to be analyzed
Col. 27-30	Beginning month and day of desired burning season
Col. 32-33	Last year of meteorological data to be analyzed
Col. 34-37	Ending month and day of desired burning season
Col. 39-80	Identifying information

Data cards—VARIBL—one card for each variable in prescription

Col. 1-6	VARIBL
Col. 8-9	Variable number from list below:

1. Drybulb temperature (°F)
2. Relative humidity (%) (for data sets other than Fire Weather Data Library, assign relative humidity to "other variable.")
3. Wind direction (numbers representing 8 cardinal points. Ex: NE = 1, E = 2, . . .)

   Note: For wind direction prescription limits which bracket north, enter the larger direction number as the lower limit in columns 10-12 and the smaller direction number in columns 13-15. Ex: Col. 12 = 7 and col. 15 = 1. This will set an acceptable range of wind directions from and including NW through and including NE.
4. Wind speed (mph)
5. 10-hour fuel moisture (%)
6. Maximum temperature (° F)
7. Minimum temperature (° F)
8. Maximum relative humidity (%)
9. Minimum relative humidity (%)
10. Precipitation amount (inches, tenths, and hundredths; no decimal)
11. Do not use
12. Other variables
13. Other variables
14. Other variables

Col. 10-12	Lower limit of prescription variable (right justify, units specified above)
Col. 13-15	Upper limit of prescription variable (right justify, units specified above)
Col. 16-45	Name of variable

Unless otherwise specified with a FORMAT card, the format used in the Fire Weather Data Library will be assigned. A FORMAT card is needed if items 12 and higher are used. The format must be compatible with variable list—Station no., year, month, day, N(1), N(2). . .N(10) where the N's are integer variables.

Data card—variable format card (optional)

Col. 1-6	FORMAT
Col. 7-78	Conversion specifications Note: if relative humidity is being used without temp from Fire Weather Data Library tapes and if a variable format card is required allow for temp and moisture index to be read in as next to last and last variables (i.e., format should end with T14,I3,T61,I1).

The program PRESCRB is expecting the input weather data to be on file 15. The previous runstream took care of this. If the user is using data from a source other than the National Fire Weather Data Library, the requirements are that the data file consist of single card records and be assigned to file 15. Further requirements are detailed under the variable format data cards.

Program Output

The output from PRESCRB includes the following:

Station.—The first line of the output displays the number of the station (fig. 3A) for which the analysis was performed, the elevation of the station (fig. 3B), and some identifying information such as the name of the station (fig. 3C). This information is provided by the user.

Prescription.—The ranges of the variables selected by the user to define the prescription are listed (fig. 3D).

Season.—The season (fig. 3E) and years (fig. 3F) of the weather data which are included in the analysis are shown after the prescription. The dates of the desired season are provided by the user.

Quartiles.—Quartiles are determined by counting the number of burn days, i.e., the days on which all conditions in the prescription are satisfied, in each year, ranking the counts in ascending order, and selecting the count after one-fourth, one-half, and three-fourths of the years. Hence, in the long run, 75% of the years will have at least as many days suitable for burning as the smaller number (fig. 3H), and only 25% of the years will have more burning days than the larger number. The 50-50 point or the median is the middle number (fig. 3I). Fifty percent of the years will have more than the median and 50% will have less.

Confidence limits on median.—The quartiles are estimates of the true values. That is, the data available are used to estimate the true quartile values. The more data available, the better the estimates. The amount of error which may be involved in estimating the median is determined first by finding the sample values on both sides of the median which contain the 90% confidence limits on the median. Then the probability that the true median will fall between those sample values is computed. Hence, in the sample (fig. 3J) it was determined that there is a probability of 85% that the true median falls between the sample values of 46 and 52 burning days per year. This information is a clue to the credibility of the median estimate. A probability level $\leq 90\%$ coupled with confidence limits wide enough to include the quartile values is indicative of a data sample too small to contain enough information to provide a good estimate. A planner can have more faith in the numbers he works with if he knows how much uncertainty is associated with those numbers.

Annual march of burn days.—An important piece of planning information is how the burn days are distributed through the season. This is presented as the average number of burn days in successive 10-day periods (fig. 3K). (Note: A value of −0.0 indicates there were insufficient data to calculate an acceptable average value.) These can be plotted on a piece of graph paper to show the portion of the season which favors the occurrence of burning days. For those months with 31 days, the extra day is included without comment in the 21-30 group. That explains why for July 21-30 and August 21-30 in figure 3 it was possible to accumulate 260 and 259 days from only 24 years of data (fig. 3G).

If, as a result of the information, it is decided to concentrate the burning efforts during a certain period of the season, it would then be wise to rerun the PRESCRB program specifying this new season to get a more accurate estimate of the burning day quartiles.

Length of burning periods.—Because of vagaries in the climate, burning days may occur singly or in pairs, or may occur typically in longer periods of, say, 4 or 5 days. To determine this information the program keeps a count of the number of days in each burning period (fig. 3L). A burning period is a single day or consecutive days preceded and followed by no-burn days. The count of the number of burning periods of exactly n days long which were encountered in the data is displayed as a tabulation of period lengths.

The purpose of these numbers is to help the manager form an objective picture of how the burning days are dispersed through the season. They could occur mostly in single days, or in pairs of days, or if there is a strong seasonal component, long strings of burning days could occur. The information obtained from this method of displaying the data should be useful in planning a burning schedule.

Observed counts and probabilities of tomorrow's conditions.—Often as sensory observers of the weather we formulate erroneous impressions of how persistent or constant our weather is. We are often under the impression that in the summer one nice day follows another. Because of all the conditions which must be satisifed simultaneously, there is little assurance that one burn day will follow another. It is easy to determine just how often a burn day may be expected to follow a burn day or a no-burn day to follow a no-burn day. There are only four possible combinations of burn, no-burn days in two consecutive days:

1. burn day followed by a burn day
2. burn day followed by a no-burn day
3. no-burn day followed by a burn day
4. no-burn day followed by a no-burn day

By counting the number of times each of these combinations occurs in our data sample we can determine the percentage of time that each of the four combinations may be expected to occur (fig. 3M). In essence what we are determining is how much information about conditions tomorrow is available from conditions existing today.

The total number of occurrences in this table of conditional probabilities is the total number of pairs of consecutive days encountered. This number will be different than the total number of days because of the breaks in the continuity of the weather record.

MERG3—A Computer Program to Extract Smoke Management Information from Fire Weather Data

The computer program MERG3 has been developed to obtain for fire planners the three smoke dispersion variables discussed earlier (transport windspeed and direction and atmospheric instability) for use in the planning program PRESCRB. When it is desirable to consider the number of days that can be expected with both favorable burning conditions and favorable smoke dispersion conditions, the recommended procedure is to include in the prescription variables and limits which define acceptable smoke dispersion conditions. For example, a good dispersion day will have a transport windspeed (lookout windspeed) sufficient to move the smoke away from the area and atmospheric instability which will allow the smoke column to obtain sufficient height so it can be dispersed aloft and not near the ground.

The data for such an analysis can be obtained from the simultaneous fire weather observations from a high elevation station such as a lookout and a low elevation station not more than 40 air miles away. The windspeed and direction at the lookout will provide an approximation to the transport windspeed and direction. The temperature difference between the two stations can be used to estimate the free-air (atmosphere) lapse rate which can be compared to the dry-adiabatic lapse rate. For each day that weather data are available for all of the stations (high, low, and base) MERG3 computes the difference between atmospheric and adiabatic lapse rates between a high and low station and adds this information along with the high station windspeed and direction to the end of the weather record from the base station used in the planning analysis. MERG3, in fact, writes a data file with the modified weather records which can be used directly by program PRESCRB.

Instructions to Execute MERG3

The runstream shown in figure 4 will execute MERG3 and produce an output from PRESCRB.

Instructions 1-9 in figure 4 cause a data file to be created on file 15. This file consists of the weather records from the high elevation station, the low elevation station, and the base station if it is different from the previous two.

Instructions 10-18 cause execution of program MERG3 which expects input card images on file 15 and will output card images on file 14, and uses temporary files 11 and 12. Since program PRESCRB is expecting input card images on file 15, the contents of file 14 should be copied to file 15 as in instruction 18.

Instructions 19-25 cause program PRESCRB to be executed on this newly created data set.

Instructions 1-18 must be executed for each different data set created.

Program Input

As in PRESCRB, MERG3 expects two input files: a card image file with data for program execution and a file of meteorological data. The data cards for program execution define a weather station at a low elevation site, one at a high elevation site, and optionally, a base station site which may include either of the previous stations. The base station is the weather station which will be used to represent the activity site. These data cards should be ordered by station number with the lowest station number first.

```
12345678901234567890123456789012345678901234567890

@RUN
@ASG,AX FIREDATALIB*PRØGRAMS.
@ASG,A FIREDATALIB*45A-47.
@USE 2.,FIREDATALIB*45A-47.
@ASG,T 15.
@XQT FIREDATALIB*PRØGRAMS.GETDATA2
  45201270  45201277
  45250870  45250877
@FREE 2.
@ASG,T 11.
@ASG,T 12.
@ASG,T 14.
@ASG,AX CLIMATØLØGY*PRØGRAMS.
@XQT CLIMATØLØGY*PRØGRAMS.MERG3
452012 6000HIGH
452508 2800LOW
452508 2800BASE
@CØPY 14.,15.
@XQT CLIMATØLØGY*PRØGRAMS.PRESCRB
STATN 452508  2800  4 1 700601 770930 ØUTBACK RS - WAYUP LØ
VARIBL  4  5 15WIND SPEED
VARIBL  5  5 1510-HR FUEL MØISTURE
VARIBL 12 -2 99DEGREES INSTABILITY
VARIBL 13  5 50LØØKØUT WIND SPEED
FØRMAT(I6,3I2,T29,I3,T33,I3,T72,I3,T78,I3)
@FIN
```

Figure 4.—Example runstream for executing program MERG3 to prepare a data set, then analyzing that data set using program PRESCRB.

The weather data file consists of weather records from the National Fire Weather Data Library for the two or three stations specified in the program data deck. The records should be on the file in increasing order by station number then by date.

A detailed description of MERG3 program data cards follows:

Station Cards—One data card is required for each station, low, high, and base (lowest station number first)

Col. 1-6	Station number
Col. 7-11	Station elevation (right justified)
Col. 12-15	Relative location identifier—either "high," "low," or "base" (left justified). If the base station is the same as either the "high" or "low" station then the duplicate station number should be the last card.

Program Output

The output from the execution of MERG3 will be (a) one line on the printer, and (b) card images altered by the additional information written on file 14. An example of the one line of output on the printer is:

```
499 RECORDS WERE WRITTEN ON FILE 14.
```

The card images of weather data will be written on file 14 in the following format:

Col. 1-66	Base station input data in the same format as read in
Col. 72-74	Difference between computed lapse rate and adiabatic lapse rate (5.4° F). (I3)
Col. 75-77	Wind direction from high station (I3)
Col. 78-80	Wind speed from high station (I3)

An end-of-file is written after the last record.

AN APPLICATION TO PRESCRIBED BURNING PLANNING

The following narrative demonstrates how climatological data are used through PRESCRB and MERG3 in a hypothetical fire use planning problem.

Suppose the Fire Management Officer of the Outback Ranger Station, Utopia National Forest, needs to treat with fire 100,000 acres of ponderosa pine every 10 years for fire reduction purposes. The long range planning problem is determining the resources needed to achieve the 10-year goal of burning 100,000 acres in this fuel type. The medium range planning problem is how to burn an average of 10,000 acres each fiscal year.

Effective planning requires the FMO know how many acres must be burned each day when weather and fuel moisture meet prescription, given the number and distribution of good burn days expected during the planning period. If the minimum number of acres needed to be burned each day is large, crew and equipment needs will be high, and missing an opportunity to burn even 1 day will result in a large backlog. If the minimum acreage is low, the FMO can trade off increases in crew and equipment against decreases in the number of days required to do the job.

The FMO uses the output from PRESCRB shown in figure 3 for planning. Recall that the yearly target for prescribed burn acreage is 10,000 acres. The filed weather data indicates there is a 50-50 chance each year will have at least 51 days suitable for burning (fig. 3I). Assuming all the days are correctly forecasted and are utilized for burning, the rate of burning must be 10,000/51 = 196 acres on each burn day. However, there is only a 50-50 chance there will be 51 days for burning. If the 50-50 odds are not good enough, then the last quartile indicates there is a 75% chance at least 44 burning days will occur (fig. 3H). Roughly this means that the burn quota for each of those burn days is 10,000/44, or approximately 227 acres. The per acre cost of burning 227 acres per day versus 196 acres per day may be higher; however, the chance of accomplishing the yearly objective of 10,000 acres prescription burned is much better if more acres are burned each day.

A planner desiring to use the median estimate should also desire to know the quality of that estimate. With 24 years of data (fig. 3G), one may surmise that the median estimate is very close to the true value, which is confirmed by the confidence limits on the median estimate. The 85% envelope lies between 46 and 52 days per day (fig. 3J), that is well within the outer quartiles.

Figure 5 is a plot of a three point running mean of the seasonal march of average burning days (fig. 3K). When the information is displayed in this fashion it is easy to see that burning days are more likely to occur early in the summer. This information can be used to plan a burning program in which the burning effort will be concentrated in the part of the season when chances of having good burning weather are best.

From figure 5 the best chance of encountering good burning weather is during the period June 11 to July 20. The recommended procedure now is to specify this specific period as the season and rerun PRESCRB. The output will provide a much better estimate of the number of burning days which can be expected during this selected 40-day period.

Looking at the distribution of burning period lengths (fig. 3L) we see that 53% of the burning periods occurred as a single burn day sandwiched between no-burn days. Twenty-three percent of the burning episodes occurred in 2-day stretches. Indications here are that since 76% of the burning periods occurred as 1- or 2-day episodes, the fire manager will have to rely heavily on the fire weather forecaster for advanced notice of burning weather and not count on long periods of weather favorable for burning.

The conditional probabilities in the box at the bottom of figure 3 show that in the data sample, 1,771 instances were found where a no-burn day followed a no-burn day and only 585 cases where a burn day followed a no-burn day. If today is not suitable for burning, there is about a 75% chance that tomorrow will not be a good day either. If today is a burn day, considering the whole season, chances are nearly 5,050 the same conditions will persist through tomorrow. For any specific time of the season these probabilities will change and the fire weather forecaster should be able to modify those probabilities for a given time of the year and specific location.

If the FMO also has smoke dispersion objectives, he must determine whether sufficient data are available for such an analysis. An inspection of the fire weather stations in the Outback Ranger Station area reveals a lookout about 35 air miles away and about 3500 feet higher in elevation. The data from this station, when used in conjunction with the data from Outback Ranger Station, should be adequate to estimate the atmospheric instability and provide estimates of transport level windspeed and direction.

Because of the smoke management considerations, the prescription is enlarged to include two smoke dispersion variables. In our new prescription we want to include only those days which in addition to acceptable fuel moisture and surface wind condition have atmospheric instability and transport windspeed conducive to good smoke dispersion. To limit an acceptable burning day to one with favorable vertical transport conditions, a prescription variable was included which imposed an acceptable range on the atmospheric instability of -1 to 99. Positive numbers correspond to favorable instability, and negative numbers indicate stability (negative instability). In setting this prescription, the lower limit (-1) was set because it was reasoned heat from the fire would provide enough buoyancy to overcome a small amount of negative instability. This reasoning may not hold true for fires of low intensity, in which case the prescription limits should be adjusted accordingly. The transport windspeed (lookout windspeed) was considered to be acceptable if greater than 10 mph. Now MERG3 and PRESCRB are run with the new prescription using the runstream in figure 4. Only half the years have 11 days meeting the new prescription with the smoke management constraints. The 25% and 75% limits are 12 and 10 days per year. Similar reductions in numbers of burn days expected occur when additional variables are added to a prescription. The reduced number of burning days for the new example prescription is the result of both a shortened observation season at the lookout and the stricter prescription.

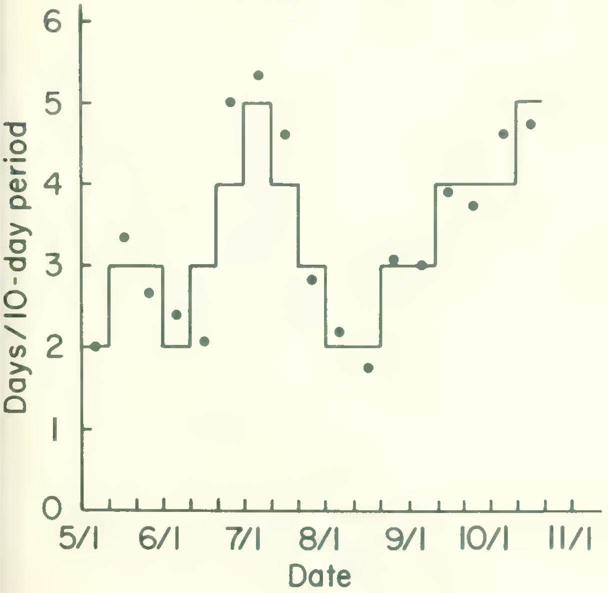


Figure 5.—A plot of the seasonal march of burning days from figure 1 (dots are 10-day averages; solid lines are 30-day running averages rounded to nearest whole day).

SUMMARY

The use of the probabilistic information in this analysis is mostly subjective. For long range planning, the median or quartile values of the number of days meeting prescription are useful in establishing target burn acreages. Knowing in what part of the season burning days are most likely to occur is useful middle to long range planning information. Seasonal scheduling of burning activities should be easier with this kind of prior information.

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Keywords: Prescribed fire, fire use planning, climatology, computer program.

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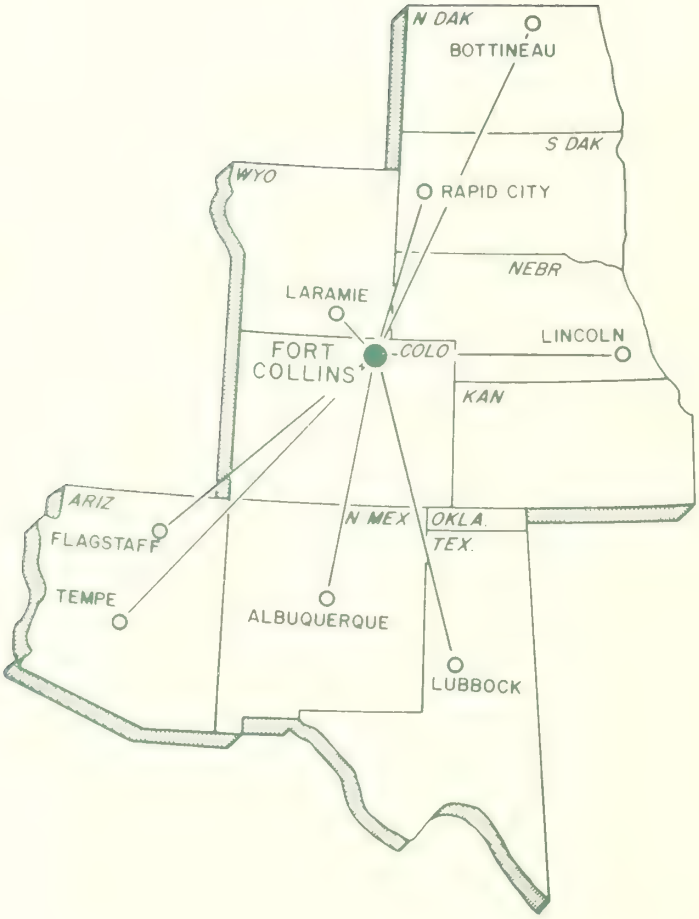
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Plants of the Arizona Chaparral

O. D. Knipe, C. P. Pase,
and R. S. Carmichael

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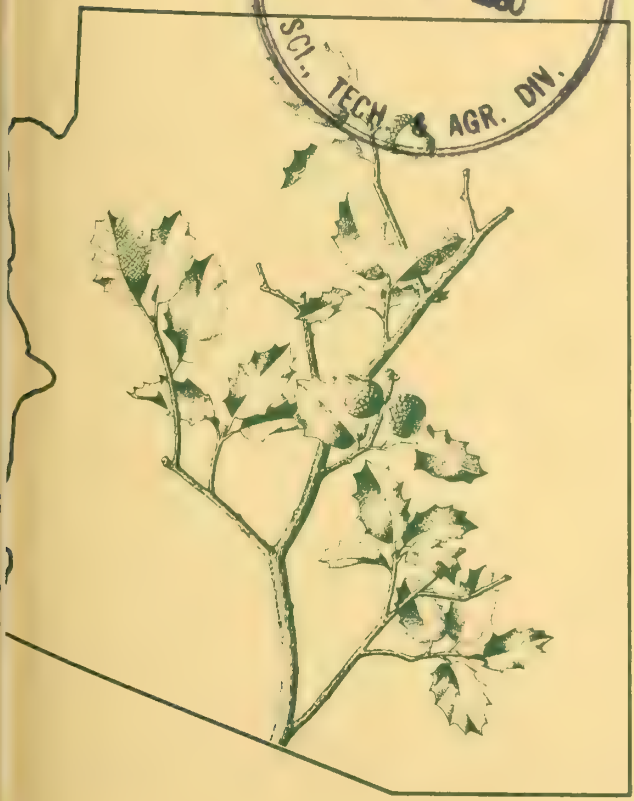

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Abstract

Lists the associations within the chaparral type, and the speci that have been identified in the type, including scientific name common names, duration, and relative abundance. As an aid identification, family names are given as are distinguishi characteristics such as flower color, specific habitat requiremen unusual growth characteristics, etc. The species are listed accor ing to growth form: grasses, forbs and grasslikes, half shru shrubs, and trees.

G eral Technical Report RM-64 July 1979

Plants of the Arizona Chaparral

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Introduction

Plants common to the chaparral type in Arizona (fig. 1) are listed. the species listed, only about 20% are of major importance; the nainder are seldom encountered and may be widely scattered roughout the type or only locally abundant. Only a few species e dominants in other than relatively small, localized areas. The sociations within the type are named after these dominants armichael et al. 1978):

1. Shrub live oak—mixed shrub (Qutu[2] mixed shrub)
2. Shrub live oak—mountainmahogany (Qutu-Cebe, or Cebr)
3. Mountainmahogany—mixed shrub (Cebe- or Cebr- mixed shrub)
4. Pointleaf manzanita (Arpu)
5. Pringle manzanita (Arpr)
6. Shrub live oak—datil yucca—yellowleaf silktassel (Qutu-Yuba-Gafl)
7. Arizona white oak—yellowleaf silktassel—Emory oak (Quar-Gafl-Quem)
8. Arizona cypress-shrub live oak (Cuar-Qutu)
9. Yerba santa-desert ceanothus (Eran-Cegr)

The most widespread and frequent dominant is shrub live oak utu); this species, either as the principle dominant or in associa- n with one of the mountainmahoganies (Cebe or Cebr), domi- tes more than 50% of the Arizona chaparral. Other important and idespread, though never dominant, shrubs are hollyleaf ckthorn (Rhcr), Parry agave (Agpa), California brickellia (Brca), unkbush sumac (Rhtr), sugar sumac (Rhov), and Wright silktas- l (Gawr). Other trees that are likely to be encountered over much the type are the junipers (Jumo, Jude, and Juos), Gambel oak uga), pinyon (Pied), and Ponderosa pine (Pipo).

The most commonly encountered half-shrubs are broom meno- ra (Mesc), broom snakeweed (Gusa), Wright buckwheat (Erwr), nstemons (*Penstemon* spp.), groundsels (*Senecio* spp.) and obemallows (*Sphaeralcea* spp.).

Many forbs are common and sometimes abundant, including ains pricklepoppy (Arin), milkweeds (*Asclepias* spp.), locos *stragalus* spp.), asters (*Aster* spp.), spiderlings (*Boerhaavia* p.), thistles (*Circium* spp.), tansymustards (*Descurainia* spp.), abanes (*Erigeron* spp.), filaree (Erci), spurges (*Euphorbia* spp.), orningglories (*Ipomoea* spp.), penstemons (*Penstemon* spp.), oundsels (*Senecio* spp.), globemallows (*Sphaeralcea* spp.), and right's verbena (Vewr).

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[2] *Species symbols, formed from the first two letters of each of the o words making up the scientific names, are used as identifiers in e text in place of full botanical names; species symbols are formed this way for field recording (Nickerson et al. 1976).*

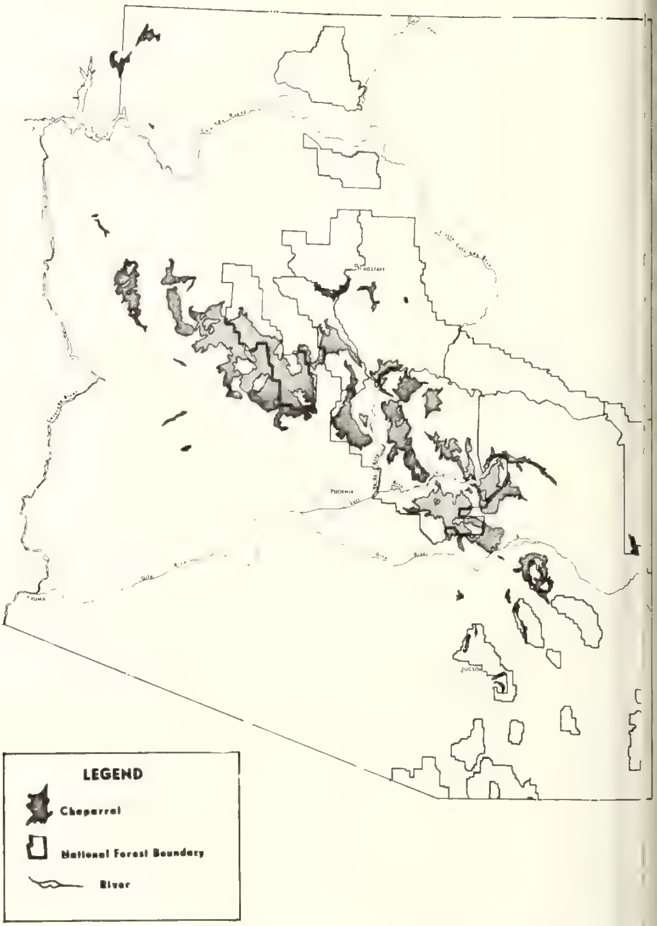

Figure 1. Extent of the chaparral vegetation type in Arizona.

Perennial grasses most likely to be encountered are blue grama Bogr), sideoats grama (Bocu), hairy grama (Bohi), wolftail (Lyph), hreeawns (*Aristida* spp.), squirreltail (Sihy), cane bluestem Anba), bullgrass (Muem), longtongue mutton bluegrass (Polo), nd the introduced lovegrasses, weeping (Ercu), Lehmann (Erle), nd Boer (Erch). The most abundant annual grasses are stinkgrass Erci), common witch-grass (Paca), sixweeks fescue (Feoc), sixweeks grama (Boba), needle grama (Boar), wild oat (Avfa), and red foxtail) brome (Brru); red brome is a very prominant winter annual t elevations below 5,400 feet. It does not occur in abundance at higher elevations.

rrangement and Explanation

Scientific names of forbs, half-shrubs, shrubs and trees generally ollow Kearney and Peebles (1960), while their common names ollow Kelsey and Dayton (1942)—in some cases common names used locally are given in parenthesis following the "standard" of Kelsey and Dayton. Scientific and common names of grasses generally follow Hitchcock (1960). As an aid to identification we have noted:

1. The duration (annual, biannual, or perennial) immediately following the scientific name of each species for grasses and forbs.
2. The family name for the forbs, half-shrubs, shrubs, and trees, plus the subfamily for legumes and the tribe for grasses.
3. The page number in Kearney and Peebles where family key begins for each forb, half-shrub, shrub, and tree, and in Hitchcock for each grass tribe (appendix 2).
4. Flower color, except for species where flowers are inconspicuous or have no petals. In the case of composites, the flower color refers to the ray flowers (abbreviations for flower colors are given in appendix 3.)
5. Easily recognized identifying characterisics (a glossary of terms used is included in appendix 4.)
6. Relative abundance.

Fire plays an important role in the environment of the Arizona chaparral. The dominant shrubs have adaptations which enable hem to maintain dominance under the influence of recurrent burning. Knowledge of their fire-adaptive characteristics is ometimes helpful in identification. For this reason, these characeristics are listed in appendix 6.

The names of some species mentioned have been changed since Kearney and Peebles (1960) and Hitchcock (1960) were printed. The old names are retained in the list to simplify matters for most eaders. Species whose names have recently been changed are ndicated by a †, and the new name is given in appendix 7.

Grasses (Gramineae)

Species abbr.	Scientific and common name and duration[1]	Tribe[2]	Distinguishing characteristics and relative abundance[3]
Agex	*Agrostis exarata* P Spike bentgrass	Agr	Moist sites; uncom
Anba †	*Andropogon barbinodis* P Cane bluestem	And	Nodes bearded; com
Anca-2*	*A. caucasicus* P Caucasian bluestem	And	Plant reddish; uncom
Anci †	*A. cirratus* P Texas beardgrass	And	Nodes bearded, plant pale purpl ; uncom
Anha	*A. hallii* P Sand bluestem	And	Rhizomatous; uncom
Anis*	*A. ischaemum* P East Indies bluestem	And	Uncom
Ansc †	*A. scoparius* P Little bluestem	And	Internodes hairy; uncom
Arad	*Aristida adscensionis* A Sixweeks three-awn	Agr	Awns equal 10-15 mm summer mo s; com
Arar-1	*A. arizonica* P Arizona three-awn	Agr	Awns equal, 10-15 mm; com
Ardi	*A. divaricata* P Poverty three-awn	Agr	Awns equal, 10-15 mm; com
Arfe-1	*A. fendleriana* P Fendler three-awn	Agr	Leaves basal, curly, awns equal 6- n; com
Argl-1	*A. glabrata* P Santa Rita three-awn	Agr	Awns equal, 2-3 cm; uncom
Argl-2	*A. glauca* P Blue three-awn	Agr	Awns equal, 1.5-2.5 cm; com
Arha	*A. hamulosa* P Desert three-awn	Agr	Central awn straight, 2-2.5 cm, l al awns 5-10 mm; com
Arlo	*A. longiseta* P Red three-awn	Agr	Awn equal 6-8 cm, plant reddish; m

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[1] *A-annual; P-perennial; biA-bi-annual*

[2] *See appendix 1 for explanation of tribe abbreviations.*

[3] *See appendix 5 for explanation of importance designations.*

**Introduced species*

† *Indicates the specific name has been changed since Kearney and Peebles (196 nd Hitchcock (1960) were printed; new names for these species are in appendix 7*

Grasses (Gramineae)—Continued

cies br.	Scientific and common name and duration[1]	Tribe[2]	Distinguishing characteristics and relative abundance[3]
Ar	*A. oligantha* A Prairie three-awn	Agr	Awns equal, 4-7 cm; uncom
Ar	*A. orcuttiana* P Single three-awn	Agr	Central awn 5-10 mm, lateral awns obsolete to 1-2 mm; uncom
A -1	*A. pansa* P Wooten three-awn	Agr	Awns horizontal, 10-20 mm; uncom
A -3	*A. parishii* P Parish three-awn	Agr	Awns equal, 2.5 cm; uncom
A -1	*A. purpurea* P Purple three-awn	Agr	Awns equal, 3-5 cm, plant purplish; com
A 1	*A. ternipes* P Spidergrass	Agr	Panicles spreading one-half height of plant, central awn 10-15 mm, lateral awns less than 2 mm; com
A	*A. wrightii* P Wright three-awn	Agr	Awns equal, 2 cm; com
A -1	*Arundo donax* P Giant reed	Fes	Rhizomatous, 2-6 m tall; uncom
A	*Avena fatua* A Wild oat	Ave	Resembles oats, spring annual; com
B	*Blepharoneuron tricholepis* P Pine dropseed	Agr	Spikelets single flowered; uncom
B	*Bouteloua aristidoides* A Needle grama	Chl	Resembles 3-awn; com
B	*B. barbata* A Sixweeks grama	Chl	Rosette-like plant; com
B	*B. curtipendula* P Sideoats grama	Chl	Rhizomatous; com
B	*B. eriopoda* P Black grama	Chl	Stoloniferous, woolly at base; uncom
B	*B. gracilis* P Blue grama	Chl	Leaves mostly basal; com
E	*B. hirsuta* P Hairy grama	Chl	Rachis extends beyond the spikelets; com
E	*B. rothrockii* P Rothrock grama	Chl	Weak perennial; uncom

amineae)—Continued

Species abbr.	Scientific and common name and duration[1]	Tribe[2]	Distinguishing characteristics and relative abundance[3]
Brar	*Bromus arizonicus* A Arizona brome	Fes	Winter annual; uncom
Brma	*B. marginatus* P Mountain brome	Fes	Plant of higher elevations, pub cent; com
Brri*	*B. rigidus* A Ripgut brome	Fes	Winter annual, plant spreading om
Brru-1*	*B. rubens* A Foxtail brome (Red brome)	Fes	Winter annual, plant spreading; m
Brte-1*	*B. tectorum* A Cheatgrass brome	Fes	Winter annual, plant spreading; com
Brtr*	*B. trinii* A Chilean brome	Fes	Winter annual, plant spreading; com
Ceci*	*Cenchrus ciliaris* P Buffelgrass	Pan	Culms abruptly bent above a otty base; uncom
Cepa	*C. pauciflorus* A Sandbur	Pan	Prostrate, fruit a burr; uncom
Cyda	*Cynodon dactylon* P Bermudagrass	Chl	Stoloniferous, rhizomatous, p trate, moist sites; uncom
Eccr	*Echinochloa crusgalli* A Barnyard grass	Pan	Rank annual; uncom
Elgl	*Elymus glaucus* P Blue wildrye	Hor	Culms bent at base; uncom
Erar	*Eragrostis arida* A Desert lovegrass	Fes	Culms branching at base; unco
Erch*	*E. chloromelas* P Boer lovegrass	Fes	Com
Erci-2	*E. cilianensis* A Stinkgrass	Fes	Disagreeable odor; com
Ercu*	*E. curvula* P Weeping lovegrass	Fes	Large bunchgrass; com
Erin-1	*E. intermedia* P Plains lovegrass	Fes	Large bunchgrass; com
Erle*	*E. lehmanniana* P Lehmann lovegrass	Fes	Com

Grasses (Gramineae)—Continued

cies br.	Scientific and common name and duration[1]	Tribe[2]	Distinguishing characteristics and relative abundance[3]
E	*E. mexicana* A Mexican lovegrass	Fes	Uncom
E	*E. pilosa* A India lovegrass	Fes	Uncom
E 3*	*E. superba* P Wilman lovegrass	Fes	Uncom
E 1*	*E. trichodes* P Sand lovegrass	Fes	Uncom
F 1	*Festuca arizonica* P Arizona fescue	Fes	Higher elevations, in pine fringe, com
F y	*F. myuros* A Rattail fescue	Fes	Unconm
F †	*F. octoflora* Sixweeks fescue	Fes	Com
F †	*F. pacifica* A Pacific fescue	Fes	Uncom
H -1	*Heteropogon contortus* P Tanglehead	And	High elevations, awns twisted and tangled; uncom
H	*Hilaria belangeri* P Curly mesquite	Zoy	Stoloniferous, leaves, basal, curly; uncom
H	*H. jamesii* P Galleta	Zoy	Rhizomatous, bases often decumbent; uncom
H u	*H. mutica* P Tobosa	Zoy	Rhizomatous; uncom
H	*Hordeum jubatum* P Foxtail barley	Hor	Uncom
H	*H. leporinum* A Mouse barley	Hor	Uncom
r †	*Koeleria cristata* P Prairie junegrass	Ave	Higher elevations; uncom
-2*	*Lamarckia aurea* A Goldentop	Fes	Uncom
u	*Leptochloa dubia* P Green sprangletop	Chl	Com

Grasses (Gramineae)—Continued

Species abbr.	Scientific and common name and duration[1]	Tribe[2]	Distinguishing characteristics and relative abundance[3]
Lefi	*L. filiformis* A Red sprangletop	Chl	Uncom
Leco	*Leptoloma cognatum* P Fall witchgrass	Pan	Uncom
Lyph	*Lycurus phleoides* P Wolftail	Agr	Resembles timothy; com
Muap	*Muhlenbergia appressa* P Canyon muhly	Agr	Panicles narrow; uncom
Mubr	*M. brevis* P Short muhly	Agr	Uncom
Muem	*M. emersleyi* P Bullgrass	Agr	Large bunchgrass, panicle purp h; com
Mufr	*M. fragilis* A Ticklegrass muhly	Agr	Uncom
Mulo	*M. longiligula* P Longtongue muhly	Agr	Bases of plants hard, large bunch-g s; com
Mumi-2	*M. microsperma* A Littleseed muhly	Agr	Uncom
Mumo-2	*M. monticola* Mesa muhly	Agr	Uncom
Mupa	*M. pauciflora* P New Mexico muhly	Agr	Culms wiry; uncom
Mupo-1	*M. porteri* P Bush muhly	Agr	Culms, brittle, usually under sh s; uncom
Muri-3	*M. rigens* P Deergrass	Agr	Base hard, stiff erect plant, large bu grass, moist sites; com
Muwo	*M. wolfii* A Red muhly	Agr	Culms spreading; uncom
Paar	*Panicum arizonicum* A Arizona panicum	Pan	Uncom
Paca	*P. capillare* A Common witchgrass	Pan	Com
Paha	*P. hallii* P Halls panicum	Pan	Uncom

Grasses (Gramineae)—Continued

pecies abbr.	Scientific and common name and duration[1]	Tribe[2]	Distinguishing characteristics and relative abundance[3]
hi	*P. hirticaule* A Roughstalk witchgrass	Pan	Culms simple; com
hu	*P. huachucae* P Huachuca panicum	Pan	Uncom
ob	*P. obtusum* P Vine-mesquite	Pan	Lengthy stolons; uncom
sc	*P. scribnerianum* P Scribner panicum	Pan	Uncom
st-1	*P. stramineum* A Sonora witchgrass	Pan	Uncom
vi*	*P. virgatum* P Switchgrass	Pan	Rhizomatous; uncom
st-2	*Paspalum stramineum* P Sand paspalum	Pan	Plant yellowish-green; uncom
tu*	*Phalaris tuberosa* P Bulb canarygrass	Pha	Bulbous base; uncom
bi-1	*Poa bigelovii* A Bigelow bluegrass	Fes	Uncom
bu	*P. bulbosa* P Bulbous bluegrass	Fes	Bulbous base; uncom
lo-1	*P. longiligula* P Longtongue mutton bluegrass	Fes	Com
mo	*Polypogon monspeliensis* A Rabbitfoot polypogon	Agr	Moist sites; uncom
ba-2*	*Schismus barbatus* A Mediterranean grass	Ave	Uncom
ma	*Setaria macrostachya* P Plains bristlegrass	Pan	Uncom
hy	*Sitanion hystrix* P Bottlebrush squirreltail	Hor	Cool season grower, mostly north slopes; com
ha	*Sorghum halepense* P Johnson grass	And	Rhizomatous; roadsides, swales; uncom
ob	*Sphenopholis obtusata* P Prairie wedgescale	Ave	Wet sites; uncom

Grasses (Gramineae)—Continued

Species abbr.	Scientific and common name and duration[1]	Tribe[2]	Distinguishing characteristics and relative abundance[3]
Spco	*Sporobolus contractus* P Spike dropseed	Ave	Com
Spcr	*S. cryptandrus* P Sand dropseed	Ave	Com
Stne	*Stipa neomexicana* P New Mexico feathergrass	Agr	Plumose awn; com
Stsp-2	*S. speciosa* P Desert needlegrass	Agr	Awn plumose at base; com
Trca-1	*Trichachne californica* P Arizona cottontop	Pan	Knotty-wooly base; uncom
Trmu	*Tridens muticus* P Slim tridens	Fes	Uncom
Trpi †	*T. pilosus* P Hairy tridens	Fes	Uncom
Trpu †	*T. pulchellus* P Fluffgrass	Fes	Rosette growth form; uncom

Forbs and Grasslike Plants

pecies abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
in	*Abutilon incanum* P Indianmallow abutilon	Malv	O, Y, leaves thick, woolly; com
pa	*A. parvulum* P Little abutilon	Malv	P, leaves thin, sparse hairs, dark green above; com
ne	*Acalypha neomexicana* A New Mexico copperleaf	Euph	RW, nettle-like, erect; com
mi	*Achillea millefolium* P Yarrow	Comp	Leaves pinnate, aromatic; com
n	*Allionia incarnata* P Trailing allionia	Nyct	P, Pu, stems prostrate and trailing; com
u	*A. pumila* P Dwarf allionia	Nyct	P, Pu, decumbent to prostrate, pubescent; uncom
na	*Allium macropetalum* P Largeflowered onion	Lili	Ro-Pu to nearly W, scapose, EG; uncom
a	*A. palmeri* P Palmers onion	Lili	Ro-Pu to nearly W, scapose, EG; com
fi	*Amaranthus fimbriatus* Fringed amaranth	Amara	V, upright, few branches, sparse leaves; com
gr	*A. graecizans* A Tumbleweed amaranth	Amara	BGr, purplish, prostrate, much branched stems; com
ps	*Ambrosia psilostachya* P Western ragweed	Comp	Y, running rootstocks; com
in	*Amsinckia intermedia* A Fireweed fiddleneck	Bora	Y, O, bristly erect herbs, fruit a nutlet, flowers in scorpioid cymes; uncom
tu	*Anemone tuberosa* P Tuber anemone	Ranu	P, Pu, erect scape-like stems, leaves basal tuberlike root; uncom
TE	*Antennaria spp.* P Pussytoes	Comp	W, dwarf, tomentose, stoloniferous, leaves mostly in basal rosette; uncom

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See appendix 2 for explanation of family abbreviations.

'See appendix 3 for abbreviations and definitions (flower color not noted when flowers are onspicuous).

'Introduced species.

†Indicates the specific name has been changed since Kearney and Peebles (1960) and chcock (1960) were printed; new names for these species are presented in appendix 7

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Apme	*Apocynum medium* P Dogbane	Apoc	P, erect-leafy stems; uncom
Aqch	*Aquilegia chrysantha* P Golden columbine	Ranu	Y, large, showy flowers, wet s; uncom
Arpe	*Arabis perennans* P Perennial rockcress	Cruc	P-Pu, woody foot at the base of t; uncom
Arva	*Arceuthobium vaginatum* Southwestern dwarf mistletoe	Lora	Without chlorophyll, parasitic on n-fiers; com
Ardo-2	*Arenaria douglasii* A Douglas sandwort	Cary	W-Cr, much branched from near e, tufted; com
Arfe-2	*A. fendleri* P Fendler sandwort	Cary	W-Cr, plants bluish green, gras e plant; com
Arsa	*A. saxosa* P Rock sandwort	Cary	W-Cr, plants compact, stems m d; uncom
Arin	*Argemone intermedia* P Plains pricklepoppy	Papa	W, yellow sap, plants prickly; co
Arwa	*Aristolochia watsoni* P Watson dutchmanspipe	Aris	G, Br-Pu, trailing stems from a k root, leaves purplish; uncom
Arca-4	*Artemisia carruthii* P Carruth sagebrush	Comp	Y, leaves tomentose, aromatic; co
Ardr-2	*A. dracunculoides* P Falsetarragon sagebrush	Comp	W, cr, non-aromatic; com
Arlu	*A. ludoviciana* P Louisiana sagebrush	Comp	Cr, plant tomentose, aromatic; un
Arpa	*A. pacifica* P Artemisia	Comp	Ruse, EG-hairy, non-aromatic; co
Asas	*Asclepias asperula* P Milkweed	Ascl	Cr, Y, sap milky; com
Asca †	*A. capricornu* P Antelope-horns	Ascl	GY and MA, sap milky, stems de -bent; com
Assu-1	*A. subverticellata* P	Ascl	GW, stems leafy, sap milky; unco
Astu	*A. tuberosa* P Butterfly milkweed	Ascl	O or Sc, stems leafy; uncom
Asar-2	*Aster arenosus* P Sand aster	Comp	W, cr; com

Forbs and

ecies br.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
-2 †	*A. bigelovii* A Bigelow aster	Comp	La, Pu, stems glandular-hispid; com
	A. exilis A Bag aster	Comp	P, Pu, along streams, succulent; uncom
-2 †	*A. tagetinus* P Arizona aster	Comp	Pu; com
-1 †	*A. tanacetifolius* P Tansyleaf aster	Comp	Pu; com
i*	*Astragalus cicer* Cicer milkvetch	Legu Papil	Pu; uncom
-3	*A. lentiginosus* P Specklepod loco	Legu Papil	V, prostrate; com
o	*A. nothoxys* P Sheep loco	Legu Papil	Pu, prostrate, pubescent; com
u	*A. nuttallianus* A Nuttall loco	Legu Papil	La, Pu, leaves pubescent above; com
e	*A. tephrodes* P Towline loco	Legu Papil	Pu, spreading, erect, higher elevations; uncom
o	*A. wootoni* A Wooton loco	Legu Papil	Stems decumbent at base, then ascending, leafy, inflated mottled pods; com
	Athysanus pusillus A Tiny athysanus	Cruc	Y, small, pubescent, stems thread-like; com
†	*Baeria chrysostoma* A Branchy goldfields	Comp	Y, low, slender plants; com
i	*Bahia biternata* P Chaparral bahia	Comp	Y, stems glandular; com
u	*Baileya multiradiata* P Desert baileya (Desert marigold)	Comp	Y, plants gray, tomentose; com
o-1	*Boerhaavia coccinea* P Scarlet spiderling	Nyct	Pu-R, long trailing stems, vicid band around intemodes; com
n-1	*B. intermedia* A Desert spiderling	Nyct	W-P, stems decumbent or erect, spreading; com
p	*B. spicata* A Spike spiderling	Nyct	W-P, stems villous; com

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Bohi	*Bommeria hispida* P Rock fern	Polyp	Fern, EG, segments pilose above; co
Boin-2	*Bowlesia incana* A Creeping bowlesia	Umbe	GW, suberect to prostrate; com
Brju*	*Brassica juncea* A or biA Indian mustard	Cruc	Y, leaves in rosette; com
Brni*	*B. nigra* A or biA Black mustard	Cruc	Y, stems hairy; com
Cafl-2	*Calochortus flexuosus* P Weakstem mariposa	Lili	Li, bulbous, decumbent; com
Cagu	*C. gunnisoni* P Gunnison mariposa	Lili	W-LaPu-Y, bulbous; com
Cake	*C kennedyi* P Desert mariposa	Lili	Y, Sc, O, bulbous; com
Cabu	*Capsella bursapastoris* A Shepherds-purse	Cruc	W, root leaves in a rosette, seed wedge shaped; uncom
Caat	*Carex athrostachya* P Slenderbeak sedge	Cype	The leaves of all *Carex* are triangula cross section and the plants grasslike; uncom
Cabo	*C. bonplandii* P	Cype	Uncom
Cage	*C. geophila* P Dryland sedge	Cype	Uncom
Capr	*C. praegracilis* P Silver sedge	Cype	Uncom
Case-2	*C. serratodens* P Sawtooth sedge	Cype	Uncom
Casu	*C. subfusca* P Sedge	Cype	Uncom
Cath	*C. thurberi* P Sedge	Cype	Uncom
Caco-1	*Cassia covesii* P Hairy senna	Legu Caesa	Y, pubescent; com
Cale-4	*C. leptadenia* A Slender senna	Legu Caesa	Y, pubescent; com

Forbs and Grasslike Plants—Continued

pecies abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
ach	*Castilleja chromosa* P Showy paintbrush	Scro	Sc, O, plant grayish, stiff hairy herbage; uncom
aco-3	*C. confusa* P Common paintbrush	Scro	R; com
ain-2	*C. integra* P Wholeleaf paintedcup	Scro	Sc, leaves smooth above, hairy below; uncom
ali-1	*C. linariaefolia* A Wyoming paintbrush	Scro	R, Y, leaves thread-like; uncom
ami-4	*C. minor* A Little paintbrush	Scro	R, found around springs or brooks; com
ami-1	*Caucalis microcarpa* P False-carrot	Umbe	W, hairy herbage, umbelliferous; uncom
hfe-1	*Cheilanthes feei* Fee lipfern	Polyp	Fern; uncom
hfe-2	*C. fendleri* P Fendler lipfern	Polyp	Fern; uncom
hpa	*C. parryi* P	Polyp	Fern, EG—segments hairy above, white villous below; uncom
hwo	*C. wootoni* Wooten lipfern	Polyp	Fern of rock ledges; uncom
hfr	*Chenopodium fremontii* Fremont goosefoot	Chen	G, a prominent plant after fire; com
hgr	*C. graveolens*	Chen	G, somewhat spinescent; uncom
hbr	*Chorizanthe brevicornu* A Horned chorizanthe	Polyp	W, leaves in basal rosette, not persistent, prickly, yellowish; uncom
Ciar	*Cirsium arizonicum* P Arizona thistle	Comp	W, leaves prickly, plant grayish, rocky slopes; uncom
Cine	*C. neomexicanum* P Lavender thistle	Comp	La, leaves prickly, plant grayish; com
llu	*Cleome lutea* A Yellow spiderflower	Capp	Y, ill-smelling, erect, along streams; uncom
lse	*C. serrulata* A Bee spiderflower	Capp	PuP or W, erect, tall, roadsides; uncom

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Clrh	*Clarkia rhomboidea* A Polkadot clarkia	Onag	Ro Pu; uncom
Clli	*Clematis ligusticifolia* P Western virginsbower	Ranu	Cr, climbing, woody base; uncom
Cogr	*Collomia grandiflora* A Bigflower collomia	Pole	Cr, P, A, flowers in dense term d heads; com
Coli-1	*C. linearis* A Slenderleaf collomia	Pole	Pu, P, W, flowers in dense term d heads; com
Copa-2	*Comandra pallida* P Common comandra	Sant	W, P, root parasite, flower urn-sha l; uncom
Come †	*Conopholis mexicana* P Squaw root	Orob	Br, parasite, roots of pine, cypress, k and walnut, without chloroph l; uncom
Coin	*Convolvulus incanus* P Nebraska glorybind	Conv	P, Pu, stems trailing, climbing e; uncom
Coli-2	*C. linearilobus* P Narrowleaf bindweed	Conv	P, W, vine, stems trailing, climb g; uncom
Coco	*Conyza coulteri* P Conyza	Comp	W, broomlike; uncom
Coau	*Corydalis aurea* biA Golden corydalis	Papa	Y, uncom
Crfe	*Cryptantha fendleri* A	Bora	W, slender plant; com
Crne	*C. nevadensis* A Nevada hiddenflower	Bora	Y, stiff hairs on stems; uncom
Cudi	*Cucurbita digitata* P Finger gourd	Cucu	Y, trailing stems, thick root, ro h, hairy foliage; uncom
Cuum	*Cuscuta umbellata* P Dodder	Conv	W, parasitic, with twining stems, e, without chlorophyll; com
Cybu	*Cymopterus bulbosus* P Chimaya	Umbel	W, leaves basal, long taproot, cool a-son plant; uncom
Cyst-2	*Cyperus strigosus* P Tall flatsedge	Cype	Grass-like, stems triangular in ss section, moist sites; uncom

Forbs and Grasslike Plants—Continued

pecies abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
fr	*Cystopteris fragilis* P Brittle bladderfern	Polyp	Deciduous fern; uncom
me †	*Datura meteloides* P Sacred datura (jimson weed)	Sola	W, unpleasant odor, erect, fruit prickly; uncom
pu	*Daucus pusillus* A Southwestern carrot	Umbe	W, carrot-like; uncom
am	*Delphinium amabile* P Lonely larkspur	Ranu	B, leaves mostly basal; uncom
eob	*Descurainia obtusa* A Tansy mustard	Cruc	Y, erect, pinnate leaves; com
epi	*D. pinnata* A Pinnate tansymustard	Cruc	Y, tall, straight, grayish, leaves sparse, fruits resemble cigars; com
eso	*D. sophia* A Flixweed tansymustard	Cruc	Y; uncom
eco	*Desmanthus cooleyi* A James bundleflower	Legu Mimos	W, stems decumbent or spreading; uncom
epr	*Desmodium procumbens* A	Legu Papil	Pu, prostrate, spiderlike; com
ipu	*Dichelostemma pulchellum* P Purplehead grassnuts	Lili	BV, stems naked, all leaves arise from bulb; com
iwi	*Dithyrea wislizeni* Spectacle pod	Cruc	W, grayish or whitish plant, fruits resemble spectacles; com
rbr	*Draba brachycarpa* A Shortpod draba	Cruc	W, winter annual, stems leafy; com
rcu	*D. cuneifolia* A Wedgeleaf draba	Cruc	W, winter annual, upper stems bare; uncom
rre	*D. reptans* A Carolina draba	Cruc	W, winter annual, upper stems bare; uncom
cco-2	*Echeveria collomae* P Collom echeveria	Cras	R, stems scopose, succulent, leaves in rosette; uncom
ctr	*Echinocereus triglochidiatus* P Claretcup echinocereus	Cact	Sc or Cr, spines not hooked; uncom
cwr	*Echinopepon wrightii* A Spinycucumber	Cucu	W, slender climbing stems, fruit spiny; uncom

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Empe	*Emmenanthe penduliflora* Whispering bells	Hydr	Cr, herbage villous and glandu ; uncom
Epmi	*Epilobium minutum* A Little fireweed	Onag	W or La, exfoliating epidermis, dry s s; uncom
Erdi-3	*Eriastrum diffusum* A Woolly eriastrum	Pole	B-W, flowers cobwebby with long w e hairs; uncom
Erca-2 †	*Erigeron canadensis* A Horseweed fleabane	Comp	Y, tall rank plants along channels; n
Erco-2	*E. concinnus* P Hairy fleabane	Comp	B, La, W, yellow center, low pl s, leaves basal; com
Erdi-2	*E. divergens* A or biA Spreading fleabane	Comp	B, P, W, plant low and spreading, v- ered with soft hairs; com
Erfl-1	*E. flagellaris* A or biA Trailing fleabane	Comp	W, upright stem base, leaflets on r- ners arising from base; com
Erne-2	*E. neomexicanus* P New Mexican fleabane	Comp	W; com
Erpr	*E. pringlei* P Pringle fleabane	Comp	W, P, B, stems densely pubes t; uncom
Erce	*Eriogonum cernuum* A Nodding eriogonum	Polyg	St, Co, leaves basal; com
Erde	*E. densum* A Bunch eriogonum	Polyg	St, Co, plants spreading, low grov g; com
Erni	*E. nidularium* A or biA Birdnest eriogonum	Polyg	St, Co, intricate, incurved bran s; uncom
Erph	*E. pharnaceoides* A or biA Wirestem eriogonum	Polyg	St, Co, leaves white lanate beneath; n
Erth	*E. thurberi* A Thurber eriogonum	Polyg	St, Co, leaves basal, delicate p t; uncom
Ervi	*E. vimineum* A Broom eriogonum	Polyg	St, Co, few branched, naked stems; m
Erla	*Eriophyllum lanosum* A Woolly daisy	Comp	Y, woolly leaves; uncom
Erci-1	*Erodium cicutarium* A Filaree	Gera	V, winter annual, prostrate to ro te, corkscrew-like tails on the fruit; c

Forbs and Grasslike Plants—Continued

pecies abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
te	*E. texanum* A Texas heronbill	Gera	V, Pu, winter annual, prostrate to rosette; uncom
ca-5	*Erysimum capitatum* A Coast erysimum	Cruc	Y, O, Ma, fruit straight erect pods, herbage with harsh pubescence; com
me	*Eschscholtzia mexicana* A Mexican poppy	Papa	YO, spring annual; uncom
he-2	*Eupatorium herbaceum* P White thoroughwort	Comp	W, common after fire, plant fragrant when dry; com
ar	*Euphorbia arizonica* P Arizona spurge	Euph	Ro, red glands, leaves red tipped, most *Euphorbia* have milky juice; com
ca	*E. capitellata* P Head euphorbia	Euph	W, low spreading plant; com
de	*E. dentata* A Toothed euphorbia	Euph	Ro, erect plant, stems solitary; com
fl	*E. florida* A Flowery euphorbia	Euph	Vi, coarse plant, erect; uncom
in	*E. incisa* P Fringed euphorbia	Euph	Y, stems slender—numerous leaves reddish; com
me	*E. melanadenia* P Dark euphorbia	Euph	W, Cr, may be prostrate or low spreading; uncom
re	*E. revoluta* A	Euph	Y, low spreading, weak stems; uncom
se-2	*E. serpyllifolia* A Thymeleaf euphorbia	Euph	St, low spreading; uncom
se-3	*E. setiloba* A Yuma euphorbia	Euph	W, Cr, prostrate; com
ar	*Evolvulus arizonicus* P Arizona evolvulus	Conv	B, W, hairy herbage, erect plant; uncom
br	*Fragaria bracteata* P Bracted strawberry	Rosa	W, low growing with short rootstocks and long runners; uncom
co †	*Franseria confertiflora* P Western bursage	Comp	Uncom
he	*Funastrum heterophyllum* P Vine milkweed	Ascl	Pu, climbing twining; uncom

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Gawr-1	*Galactia wrightii* P Wright milkpea	Legu Papil	Pu, Gw, long twining stems; unco
Gaap	*Galium aparine* A Catchweed bedstraw	Rubi	Y, palmate leaves; com
Gami	*G. microphyllum* A	Rubi	Y, stems grooved and angled, the ar is whitish, palmate leaves; com
Gapr	*G. proliferum* A Bedstraw	Rubi	Y, stems angled, weak and reclini or leaning on other plants; uncom
Gagr	*Gaura gracilis* P	Onag	RW, low, much branched plant; un n
Gapa	*G. parviflora* A or biA Smallflower gaura	Onag	P, winter grower, tall plant with ft villous hairs; uncom
Geca-2	*Geranium carolinianum* A or BiA Carolina geranium	Gera	P, leaves palmately lobed, plants pi e, flowers pink, thick caudex; unco
Geca-3	*G. caespitosum* P Cranesbill	Gera	Pu, downy, erect and horizontal st s; com
Geer	*G. eremophilum* P Solitary geranium	Gera	P, La, leaves palmately lobed, s is usually decumbent; uncom
Giag †	*Gilia aggregata* P Skyrocket gilia	Pole	R, stems erect; com
Gigi	*G. gilioides* A Common gilia	Pole	B, V, along streams; com
Gimu	*G. multiflora* P Woody gilia	Pole	B, La, plant pubescent; uncom
Gisi	*G. sinuata* A Sky gilia	Pole	W, P, stems erect, scape-like; com
Gite	*G. tenuiflora* A Slenderflower gilia	Pole	PuP, stems erect, scape-like; unco
Gnwr	*Gnaphalium wrightii* P Wright cudweed	Comp	Y, gray—woolly leaves in basal ro e, EG; com
Hacu †	*Hopplopappus cuneatus* P Wedgeleaf goldenweed	Comp .	Y, thread-like leaves; com
Hagr †	*H. gracilis* P	Comp	Y, spatula shaped leaves, leaf tip nd phyllaries spinescent tiped; unco

Forbs and Grasslike Plants—Continued

pecies abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
edr	*Hedeoma drummondii* P Drummond falsepennyroyal	Labi	V, slightly decumbent at base, covered with fine white hairs; uncom
eob	*H. oblongifolium* P Longleaf falsepennyroyal	Labi	V, plant erect, stiff stems; uncom
ean	*Helianthus annuus* A Common sunflower	Comp	Y, coarse up to 6 ft tall; com
ecu	*Heliotropium curassavicum* Quail plant	Bora	Pu, very succulent, moist sites;
emi	*Hemicarpha micrantha* A Dwarfsedge	Cype	Small, dwarfy, slender-tufted stems, along streams, grass-like; uncom
esu	*Heterotheca subaxillaris* A Camphor-weed	Comp	Y, large and coarse; com
eea	*Heuchera eastwoodiae* P Eastwood alumroot	Saxi	G, Y, woody scaly candex, leaves mostly basal; uncom
ode †	*Hoffmanseggia densiflora* A Indian rushpea	Legu Caesa	Y, flower stems scapse, creeping rootstocks; com
odr	*H. drepanocarpa* P Sicklepod rushpea	Legu Caesa	Y, thick woody taproot; com
ywr	*Hymenothrix wrightii* A	Comp	W, hairy, glandular; uncom
ba	*Ipomoea barbatisepala* A	Conv	P, often common after fire, twining stems, climbing on shrubs, trumpet shaped flowers; uncom
co	*I. coccinea* P Scarlet starglory	Conv	Sc, twining stems, trumpet shaped flowers; com
co-1	*I. costellata* A	Conv	V, stems erect, trumpet shaped flowers; uncom
hi	*I. hirsutula* A Mexican morningglory	Conv	V, twining stems, trumpet shaped flowers; com
th	*I. thurberi* P	Conv	Pu, twining stems; com
gr	*Janusia gracilis* P Slender janusia	Malp	Y, twining stems; com

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Jubu	*Juncus bufonius* A Toad rush	Junc	G, Br, along streams, grass-like, ste hollow; uncom
Juin	*J. interior* P Inland rush	Junc	G, Br, along streams, grass-like, ste hollow; uncom
Jusa	*J. saximontanus* P Rocky Mountain rush	Junc	G, Br, along streams, stems holl uncom
Kagr	*Kallstroemia grandiflora* Arizona poppy caltrop	Zygo	O, prostrate, seeds horned; com
Kapa	*K. parviflora* A	Zygo	YO, prostrate, seeds horned; com
Lagr	*Lactuca graminifolia* A Wild lettuce	Comp	B, Pu, leaves in rosette; com
Lagr-1	*Lathyrus graminifolius* P Grassleaf peavine	Legu Papil	W, P, Or, trailing or climbing, 4-si stems; uncom
Lala	*L. laetivirens* P Aspen peavine	Legu Papil	O, vine, trailing or climbing, 4-si stems; uncom
Lagl	*Layia glandulosa* Whitedaisy tidytips	Comp	W, low plants, bristly leaves; unco
Lede	*L. densiflorum* A Peppergrass	Cruc	W, diffusely branched; com
Leme	*Lepidium medium* A or biA Common peppergrass	Cruc	W, erect, soft pubescence; com
Lefe	*Lesquerella fendleri* P Fendler bladderpod	Cruc	Y, leaves mostly basal, fruit infla com
Liau	*Linanthus aureus* A Yellow trumpet	Pole	Y, spring annual, diffusely branc uncom
Libi	*L. bigelovii* A Painted trumpet	Pole	Cs, erect plant, covered with a m down, scapelike; uncom
Lite-2	*Linaria texana* A or biA Texas toadflax	Scro	B, erect; uncom
Lile	*Linum lewisii* P Lewis flax	Lina	B; uncom
Liin	*Lithospermum incisum* P	Bora	Y, trumpet shaped flowers; uncom
Loca	*Lobelia cardinalis* P Cardinal flower	Camp	R, RY, erect; uncom

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
one	*Lomatium nevadense* P	Umbe	W, scapose; uncom
ohu	*Lotus humistratus* A Foothill deervetch	Legu Papil	Y, O, decumbent or prostrate; uncom
opu	*L. purshianus* A Spanish clover	Legu Papil	W-P, erect; com
osa	*L. salsuginosus* A Prostrate deervetch	Legu Papil	Y, O, decumbent or prostrate; uncom
Loto	*L. tomentellus* A Desert deervetch	Legu Papil	Y, O, decumbent or prostrate; com
Lowr	*L. wrightii* A Wright deervetch	Legu Papil	Y, O, stems limber, drooping; com
Lubi	*Lupinus bicolor* A Bicolor lupine	Legu Papil	VB and W, spring annual, herbage villous; com
Luco	*L. concinnus* A or biA Bajada lupine	Legu Papil	Pu, spring annual, villous; uncom
Lupa-2	*L. palmeri* Palmer lupine	Legu Papil	V, stems densely pubescent; com
Lusp	*L. sparsiflorus* A or biA Coulter lupine	Legu Papil	VB, W, winter grower, not succulent, green when dry; com
Lusu	*L. succulentus* A or biA Arroyo lupine	Legu Papil	VB, unusually large root nodules; uncom
Lyju	*Lygodesmia juncea* P Rush skeletonplant	Comp	P, Ro, leaves basal, grasslike, milky sap; uncom
Lyca	*Lythrum californicum* P California loosestrafe	Lyth	RoPu, stoloniferous, stems erect, exfoliating bark; uncom
Macl	*Malacothrix clevelandi* A Cleveland desertdandelion	Comp	Y, W, milky sap; com
Magl-2	*M. glabrata* A Smooth desertdandelion	Comp	Y, W, milky sap; uncom
Mane	*Malva neglecta* A or biA Running mallow	Malv	W, P, prostrate; uncom
Magi	*Marah gilensis* P	Cucu	Annual vine from large perennial tuber; uncom

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Maso	*Margaranthus solanaceus* A Littlecup groundcherry	Sola	GY, Pu, fruit, many-seeded globo berry; uncom
Maan	*Maurandya antirrhiniflora* P False snapdragon	Scro	VPu or carmine, climbing, twinin uncom
Mele	*Melampodium leucanthum* P Plains blackfoot	Comp	W, half shrub-like; com
Meof	*Melilotus officinalis* P Yellow sweetclover	Legu Papil	Y; com
Meal-2	*Mentzelia albicaulis* A Whitestem mentzelia	Loas	Y, small, leafy, often decumbent, leav adhere to clothing; com
Meni-2	*M. nitens* A Showy stickleaf	Loas	Y, leaves adhere to clothing; uncom
Mepu †	*M. pumila* A or biA Golden stickleaf	Loas	Y, leaves adhere to clothing, twist grayish stems; com
Mili	*Microseris linearifolia* A Narrowleaf microseris	Comp	W, Ro, La, scape-like, small, spreadi com
Migr	*Microsteris gracilis* A Slender microsteris	Pole	W, Ro, La, small, spreading, glandul uncom
Migu	*Mimulus guttatus* P Common monkeyflower	Scro	Y, from rootstocks or stolons, ere along streams, pubescent; uncom
Mina	*M. nasutus* A	Scro	Y, along streams; uncom
Mipi	*M. pilosus* A Hairy monkeyflower	Scro	Y, along streams; uncom
Miru	*M. rubellus* A	Scro	Y, R, along streams; uncom
Mibi-2	*Mirabilis bigelovii* P Weakstem four-o'clock	Nyct	B, P, Pu, weak stemmed plant; com
Mimu	*M. multiflora* P Colorado four-o'clock	Nyct	R, Pu, stems and leaves downy; com
Mopa	*Moldavica parviflora* A or biA American falsedragonhead	Labi	B, Pu; uncom
Moce	*Mollugo cerviana* A	Aizo	W, stems erect; uncom
Move	*M. verticillata* A Carpetweed	Aizo	W, stems prostrate, mat forming; unco

Forbs and Grasslike Plants—Continued

pecies abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
ome	*Monarda menthaefolia* P Mintleaf beebalm	Labi	La, RoP, leaves hairy upper side, leaf bracts pink tinted; uncom
ope-1	*Montia perfoliata* A Minerslettuce	Port	W, leaves form saucershaped disk around stem, runners, only 2 leaves per stem; uncom
yar	*Myosurus aristatus* A Bristly mousetail	Ranu	G, Y, dwarf plant, leaves basal, along streams; uncom
ycu	*M. cupulatus* A	Ranu	G, Y, dwarf plant, along streams, both species have tall column of pistils in center of flower; uncom
de	*Nama demissum* A Low nama	Hydr	PuR, leaves in rosette and at ends of branches, prostrate, hairy; uncom
at	*Nicotiana attenuata* Coyote tobacco	Sola	W, up to 6 ft tall, trumpet shaped flowers; com
itr	*N. trigonophylla* A Desert tobacco	Sola	W, sometimes perennial, wet sites, trumpet shaped flowers, sticky; com
si	*Notholaena sinuata* P Bulb cloakfern	Polyp	EG, fern, xeric sites, rhizomatous; uncom
ost	*N. standleyi* P Star cloakfern	Polyp	EG fern, xeric sites, rhizomatous; uncom
ote-2	*Nothoscordum texanum* P Mild wildonion	Lili	YW tinged P, similar to allium but no onion smell; uncom
eca-1	*Oenothera caespitosa* P Tufted eveningprimrose	Onag	W, leaves form dense tufts, flowers along them, no stems; com
eho	*O. hookeri* A Hooker eveningprimrose	Onag	Y, OR, with age, damp places; com
emi	*O. micrantha* P	Onag	Y, prostrate, hairy stems; uncom
rfa	*Orobanche fasciculata* P Broomrape (Cancerroot)	Orob	Pu, parasite on roots of oak, without chlorophyll, downy and sticky; uncom
rmu	*O. multiflora* P Broomrape (Cancerroot)	Orob	Pu Y, parasite on roots of oak, pine, walnut and cyprus, without chlorophyll, downy and sticky, uncom
rpu-1	*Orthocarpus purpurascens* A Escobito owlclover	Scro	P and Y on same plant, herbage villous; uncom

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Oxco †	*Oxybaphus coccineus* P	Nyct	R, whitish stem, thread-like leaves; co
Oxli †	*O. linearis* P	Nyct	P, glandular stems; uncom
Oxpu †	*O. pumilus* P Low oxybaphus	Nyct	P, decumbent or prostrate; com
Pafl	*Parietaria floridana* A Pellitory	Urti	BrG, small plant, stems low spreadir uncom
Pape	*P. pensylvanica* A Pennsylvania pellitory	Urit	BrG, upright plant; uncom
Pain	*Parthenocissus inserta* P Virginia creeper	Vita	Climbing or trailing ends of tendr form discs that adhere to bark, rocl etc.; uncom
Pecy	*Pectis cylindrica* A Fetid-marigold	Comp	Y, low, horizontal spreading, hai slender stems, dotted with glanc uncom
Pere-2	*Pectocarya recurvata* A	Bora	W, prostrate or spreading, slend stems; uncom
Pese	*P. setosa* A	Bora	W, erect; uncom
Pein	*Pellaea intermedia* P	Polyp	EG fern, rachis hairy; uncom
Pelo	*P. longimucronata* P	Polyp	EG fern; uncom
Pete	*P. ternifolia* P	Polyp	EG fern; uncom
Peba	*Penstemon barbatus* P Beardlip penstemon	Scro	Sc; com
Peea	*P. eatoni* P Eaton penstemon	Scro	Sc; uncom
Pepa-5	*P. parryi* P Parry penstemon	Scro	Sc, RoM; com
Pena †	*Perezia nana* P	Comp	LaP, V, dwarf plants, scented, ste wooly tufted at base; uncom
Pewr †	*P. wrightii* P	Comp	LaPu, cool season grower, flowe honey scented, woolly tufted at ba uncom
Phcr	*Phacelia cryptantha* A	Hydr	LaPu, B, often with QUTU; com

Forbs and Grasslike Plants—Continued

pecies abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
di-2	*P. distans* A Phacelia	Hydr	B, stems weak usually supported by other plants; uncom
ma	*P. magellanica* P Varileaf phacelia	Hydr	W, B, hispid, bristly; uncom
ra	*P. ramosissima* P Branching phacelia	Hydr	B, glandular pubescent, stems weak, leaning on other plants; com
ac	*Phaseolus acutifolius* A Texas bean	Legu Papil	PuP-Pu, stems trailing; uncom
wr	*P. wrightii* A Wright's bean	Legu Papil	PuP, stems trailing; uncom
ca-2	*Phoradendron californicum* P Mesquite American-mistletoe	Lora	Parasitic chiefly leguminous shrubs; com
hco	*P. coryae* P Mistletoe	Lora	Parasitic on evergreen oaks, rarely on BEHA; com
hfl	*P. flavescens* P Mistletoe	Lora	Parasitic on several tree species; com
nju	*P. juniperinium* P Juniper mistletoe	Lora	Parasitic on juniper, seldom on other trees; com
hfe	*Physalis fendleri* P Fendler groundcherry	Sola	Y, pubescent, the *Physalis* flower has a brown or purplish eye; com
hla	*P. lanceifolia* A Lanceleaf groundcherry	Sola	W; uncom
hlo-3	*P. longifolia* P Longleaf groundcherry	Sola	Y, creeping rootstocks; com
hpu	*P. pubescens* A Downy groundcherry	Sola	Y, G, erect, hairy, diffusely branched, along streams; uncom
hve	*P. versicolor* P	Sola	GY; com
lar	*Plagiobothrys arizonica* A Arizona popcornflower	Bora	W, villous, leaves purplish; uncom
lin	*Plantago insularis* A Desert indianwheat	Plan	W-clear, scapose, silvery, villous, leaves basal, winter annual; uncom
lpu †	*P. purshii* A Wooly indianwheat	Plan	St, scapose, silvery, villous, leaves basal, winter annual; com

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Plrh	*P. rhodosperma* A Redseed plantain	Plan	St, winter annual, scapose, hairy, alon streams; uncom
Plvi	*P. virginica* A Paleseed plantain	Plan	St, silvery colored, leaves basal, winte annual, moist soils; uncom
Plca-1	*Platystemon californicus* A Creamcups	Papa	Cr, along streams, fruits resemble sma ears of corn; uncom
Plca-3	*Plectritis californica* A Plectritis	Vale	P, moist soil, erect, sparsely branche uncom
Potr-2	*Polanisia trachysperma* A Roughseed clammyweed	Capp	W, Y, shady streambeds, erect plant herbage glandular, ill scented; uncon
Polo-2	*Polygala longa* P Milkwort	Polyg-1	YGPu, V, dainty plant; uncom
Posc	*Polystichum scopulinum* P Hollyfern	Polyp	Fern, deep shade, EG, segments 2 or lobed at base; uncom
Pogr	*Porophyllum gracile* P Slender poreleaf	Comp	W, Pu, woody base, oil glands on leave uncom
Pool	*Portulaca oleracea* A Common purslane	Port	Y, decumbent or prostrate; com
Posu-2	*P. suffrutescens* P Shrubby portulaca	Port	Co, tuberous taproot, erect; uncom
Pogl	*Potentilla glandulosa* P Gland cinquefoil	Rosa	Y, wet sites, pubescent; uncom
Prpa	*Proboscidea parviflora* A New Mexico devilsclaw	Mart	RPu, viscid pubescent, fruit cla shaped (large), flower may be blotch with red-purple or streaked with y low, trailing stems; uncom
Psmo	*Pseudocymopterus montanus* P Wildcarrot	Umbe	Pu, Y, long, slender taproot; uncom
Pssp	*Psilostrophe sparsiflora* P Greenstem paperflower	Comp	Y, wooly, petals papery; uncom
Psla	*Psoralea lanceolata* P Lemon scurfpea	Legu Papil	W, branched rootstock, pubescent; co
Pste	*P. tenuiflora* P Slimflower scurfpea	Legu Papil	V, branched rootstocks, pubescer uncom

Forbs and Grasslike Plants—Continued

ecies bbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
q	*Pteridium aquilinum* P Western bracken	Polyp	Fern, stems creeping; uncom
ca	*Rafinesquia californica* A California desertchicory	Comp	W, very fine stems, milky juice; uncom
ne	*R. neomexicana* A New Mexican desertchicory	Comp	W, very fine stems, milky juice; uncom
te	*Rhynchosia texana* P Texas rhynchosia	Legu Papil	Y, trailing or weakly twining stems; uncom
cr	*Rumex crispus* P Curly dock	Polyg	PuBr, along streams, erect plants, coarse; uncom
hy	*R. hymenosepalus* P Canaigre	Polyg	PuBr, sandy streambeds, erect plants, coarse; uncom
ka* †	*Salsola kali* A Common russianthistle	Chen	P, tumbleweed; com
co	*Salvia columbariae* A California chia	Labi	R, tubular flower, sage smell; uncom
an	*Sanguisorba annua* A Prairie burnet	Rosa	No petals, delicate plant; uncom
pa-2	*Scrophularia parviflora* P Figwort	Scro	V, tall erect stems, higher elevations, flowers tubular, rhizomatous; uncom
po-2	*Scutellaria potosina* P Skullcap	Labi	V, spreading pubescence, woolly base, flowers tubular, tufted stem; uncom
ar	*Selaginella arizonica* P Arizona selaginella	Sela	Megaspores yellowish or chalky white, EG, mosslike; com
ne	*Senecio neomexicanus* New Mexican groundsel	Comp	Y, woolly leaves, white woody stems, leaves often purplish; com
qu	*S. quercetorum* P Chaparral groundsel	Comp	Y, coarse tall, stems often purplish, hollow, leaves smooth with bases extending around stem; com
pr-1	*Sida procumbens* P Trailing sida	Malv	OY, prostrate; uncom
an	*Silene antirrhina* A Sleepy silene	Cary	W, P, sticky bands around stem between upper flowers; uncom
la	*S. laciniata* P Mexican silene	Cary	R, higher elevations, downy weak stems, glandular; uncom

Forbs and Grasslike Plants—Continued

Species abbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
Siir	*Sisymbrium irio* A or biA Tumblemustard	Cruc	Y, W; uncom
Sodo	*Solanum douglasii* P Douglas nightshade	Sola	B, small tomato-like fruit; com
Somi	*Solidago missouriensis* P Missouri goldenrod	Comp	Y, stems densely puberulous; com
Sosp	*Solidago sparsiflora* P Few-flowered goldenrod	Comp	Y, higher elevations; uncom
Soas	*Sonchus asper* A Prickly sowthistle	Comp	Y, coarse spiny toothed leaves, up leaves clasping; uncom
Spec	*Spermolepis echinata* A Spermolepis	Umbe	W, rhizomatous, stems hollow; unc
Spfe	*Sphaeralcea fendleri* Fendler globemallow	Malv	Gr, P, erect, pubescent, leaves palm uncom
Stco-3	*Stachys coccinea* P Texas betony	Labi	R, stems and under surfaces of lea have long hairs, plants colonize, flo tube-like; uncom
Stme	*Stellaria media* A Chickweed starwort	Cary	W, small creeping, spreading, pul cent stems; uncom
Stni	*S. nitens* A Shiny starwort	Cary	W, erect slender stems; uncom
Stex	*Stephanomeria exigua* A Stick weed	Comp	Ro, much branched, basal lobes leaves surround stem, milky sap; unc
Stpa	*S. pauciflora* P Wirelettuce	Comp	W, P, zig-zag stems forming bu tangles, milky sap; uncom
Stte	*S. tenuiflora* P	Comp	W, thread-like leaves which stand er milky sap; uncom
Thfe-2 †	*Thalictrum fendleri* P Fendler meadowrue	Ranu	W, underside of leaves downy, spre ing; uncom
Thwr	*Thelypodium wrightii* A Wright thelypodium	Cruc	W, P, smooth white plant, erect, lea basal; uncom
Thfe	*Thlaspi fendleri* P Candytuft	Cruc	W, stems not branched, capsu wedge-shaped, leaves clasping; unc
Tham-2	*Thysanocarpus amplectens* A Lacepod	Cruc	P, slender, erect, leaves clasping; unc

Forbs and Grasslike Plants—Continued

ecies bbr.	Scientific and common name and duration	Family subfamily[1]	Flower color, distinguishing characteristics and relative abundance[2]
a	*Tidestromia lanuginosa* A Wooly tidestromia	Amara	Y, prostrate, leaves white, downy; com
ex	*Townsendia exscapa* P Stemless townsendia	Comp	W, leaves tufted or form mats, scapose; com
oc	*Tradescantia occidentalis* P Prairie spiderwort	Comm	Ro, B, tuber-like roots; uncom
ne-2 †	*Tragia nepetaefolia* P Noseburn	Euph	Slender, often twining, with stinging hairs; com
te*	*Tribulus terrestris* A Puncturevine	Zygo	Y, fruit resembles goats head, prostrate, trailing; uncom
gr-2	*Trifolium gracilentum* A Pinpoint clover	Legu Papil	P, RPu, flowers droop with age; uncom
la	*T. lacerum* Cutcollar clover	Legu Papil	W, Pu; uncom
rpe	*Triodanis perfoliata* A Venus looking-glass	Comp	B, milky juice, bristly hairs low on stem; uncom
ydo	*Typha domingensis* P Dominican cattail	Typh	Br, semiaquatic; uncom
ebi	*Verbena bipinnatifida* P Dakota verbena	Verb	P, La, Pu, wavy branches which bend upward, bristly hairs, stems square; uncom
ebr	*V. bracteata* P Bigbract verbena	Verb	W, B, V, spreading, half-shrub-like, stems square; uncom
ewr	*V. wrightii* P Wright's verbena	Verb	P, La, Pu, rosette, hairy, stems square, often prominent after fire; com
epe	*Veronica peregrina* A Purslane speedwell	Scro	W, small succulent, along streams; uncom
iex †	*Vicia exigua* P Slim vetch	Legu Papil	Pu, vine, stems 4-sided; uncom
ian	*Viguiera annua* A Annual goldeneye	Comp	Y, tall, sparsely leaved, erect; com
Vofi	*Woodwardia fimbriata* P Giant chainfern	Polyp	EG, fern, wet sites in shade; uncom
asa †	*Xanthium saccharatum* A Cocklebur	Comp	W, fruits resemble porcupine eggs; uncom
ala	*Zauschneria latifolia* Hummingbird-trumpet	Onag	Sc, exfoliating epidermis, flowers trumpet shaped; uncom

Half Shrubs

Species abbr.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
Acan	*Acacia angustissima* Prairie acacia	Legu mimos	Cr, flowers in round heads, feath foliage, stems hairy, not thorny, tra tion drier sites; uncom
Aypu	*Ayenia pusilla* Slender ayenia	Ster	Fruit a warty capsule; com
Cosc	*Commicarpus scandens* Trailing commicarpus	Nyct	YW, stems weak sometimes trailing supported by other plants; uncom
Daal	*Dalea albiflora* Whiteflowered dalea	Legu	W, Pu with age, stems villous, herba ous above the base; uncom
Dafo	*D. formosa* Feather dalea	Legu	Pu; uncom
Dapa †	*D. parryi* Parry dalea	Legu	Pu, W, hairy herbage; uncom
Dypo	*Dyssodia porophylloides* Smelly dysodia	Comp	OY, leaves glandular, strong odor; c
Erfa	*Eriogonum fasciculatum* Flattop eriogonum	Poly	W, P, flowers silky villous, EG, lea pubescent; com
Erja	*E. jamesii* James eriogonum	Poly	Cr, P, flowers silky villous, long hair herbage, EG; uncom
Erwr	*E. wrightii* Wright eriogonum	Poly	W, P, EG; plant grayish; dom
Frde †	*Franseria deltoidea* Triangle leaf bursage	Comp	CR, EG, pubescent, fruit with ho tipped spines, transition drier sites; c
Gafe	*Galium fendleri* Fendler galium	Rubi	W, Y, G, all galium have square ste and small star shaped flowers, lea whorled; uncom
Garo	*G. rothrockii* Rothrock bedstraw	Rubi	Pu, leaves arranged in circles, mi prominent beneath; uncom
Gast	*G. stellatum* Bedstraw	Rubi	Gy, stems weak, often supported other plants, shiny white branches; c
Gawr	*G. wrightii* Wright galium	Rubi	R, Pu, midrib prominent benea uncom
Gusa †	*Gutierrezia sarothrae* Broom snakeweed	Comp	Y, EG, broom-like, common in o grazed and otherwise disturbed ar com

Half Shrubs—Continued

pecies abbr.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
cu †	*Happlopappus cuneatus* Wedgeleaf goldenweed	Comp	Y, leaves threadlike, transition drier sites; uncom
he †	*H. heterophyllus* Jimmyweed (rayless goldenrod)	Comp	Y, odor of turpentine, leaves entire, somewhat herbaceous, transition drier sites; uncom
ala-1 †	*H. laricifolius* Larchleaf goldenrod (turpentine brush)	Comp	Y, odor of turpentine, transition drier sites; uncom
asp †	*H. spinulosus* Ironplant goldenrod	Comp	Y, odor of turpentine, stiff smooth stems, leaves divided, transition drier sites; uncom
ico	*Hibiscus coulteri* Desert rosemallow	Malv	Y, R at base, hairy, flowers on long stalks; com
odr	*Hoffmanseggia drepanocarpa* Sicklepod rushpea	Legu Caesa	YR, leaves twice pinnately divided, stems tufted, leaves downy; com
oja	*H. jamesii* Rushpea	Legu Caesa	YR, leaves downy, very woody root and base, black dots underside of leaf segments, leaves twice pinnately divided; com
ori	*Lotus rigidus* Shrubby deervetch	Legu Papil	YO, erect; com
esc-1	*Menodora scabra* Rough menodora	Olea	Y, deciduous; com
eam	*Penstemon ambiguus* Gilia penstemon	Scro	PW, P, grass-like leaves, stems form twiggy clumps; com
ebr	*P. bridgesii* Bridges penstemon	Scro	R, flowers downy; uncom
eli	*P. linarioides* Toadflax penstemon	Scro	B, Pu, leaves basal, may form mats; uncom
epa-4	*P. palmeri* Palmer penstemon	Scro	Sc, RoM; com
eps	*P. pseudospectabilis* Desert penstemon	Scro	RoPu, whitish green leaves, upper leaves perfoliate; com
eth	*P. thurberi* Thurber penstemon	Scro	B, Ro, long, very narrow leaves; uncom

Half Shrubs—Continued

Species abbr.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
Phcr	*Physalis crassifolia* Physalis	Sola	Y, flower like a hanging bell, lea thick and downy; com
Psco	*Psilostrophe cooperi* Whitestem paperflower	Comp	Y, petals papery at maturity, wh woolly plant; rare
Saam-2	*Salvia amissa* Sage	Labi	B, gray, hairy plant, leaves triangu uncom
Selo †	*Senecio longilobus* Threadleaf groundsel	Comp	Y, gray colored; uncom
Semo	*S. monoensis* Mono groundsel	Comp	Y, very leafy; uncom
Soxa	*Solanum xanti* Purple nightshade	Sola	V, Li-Pu, stems hairy; com
Spam	*Sphaeralcea ambigua* Desert globemallow	Malv	P, W, Or, erect, pubescent, as many 100 stems from a single root, xerophy com
Spem	*S. emoryi* Emory globemallow	Malv	V-P, erect, many-flowered, pubesce uncom
Spgr-2	*S. grossulariaefolia* Gooseberryleaf globemallow	Malv	OR, pubescent, many-flowered; com
Spru	*S. rusbyi* Rusby globemallow	Malv	R, higher elevations, pubescent, th stems; uncom
Stpi	*Stanleya pinnata* Desert princessplume	Cruc	Y, coarse plants, smooth whitish stem uncom
Vide	*Viguiera deltoidea* Parish goldeneye	Comp	Y, leaves leathery, pubescent; uncom

Shrubs

cies br.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
A r	*Acacia greggii* Catclaw acacia	Legu Mimos	Y, hairy stems, hooked thorns, transition desert shrub to chaparral, uncom
A a-3	*Agave parryi* Parry agave	Amry	GPu, bluish green leaves, scapose flowering branches, loc dom
A r	*Aloysia wrightii* Wright lippia	Verb	W, B, aromatic, toothed leaves, wrinkled and bright green above, whitish below, deciduous; uncom
am	*Ambrosia ambrosioides* Ambrosia bursage	Comp	Cr, EG, fruit with hook-tipped spines, transition drier sites; uncom
a	*Amelanchier bakeri* Baker serviceberry	Rosa	W, leaves grayish green, hairy, bark smooth and ash gray. Small applelike fruits (O or Y); com
fr-1	*Amorpha fruticosa* Indigobush amorpha	Legu	Pu, twigs glandular, leaves hairy, along streams; uncom
h	*Anisacanthus thurberi* Thurber anisacanth	Acan	R, whitish, flaky bark; uncom
r	*Arctostaphylos pringlei* Pringle manzanita	Eric	W, P, wooly leaves and pedicels, leaves often rounded or subcordate at base, EG, bark red; dom
u-2	*A. pungens* Pointleaf manzanita	Eric	W, P, leaves pointed, not woolly, EG, pale or bluish, narrowed at base, bark red; com
a	*Atriplex canescens* Fourwing saltbush	Chen	Fruits 4-winged, leaves gray, salty, EG; uncom
l t	*Baccharis glutinosa* Seepwillow baccharis	Comp	W, leaves toothed, found along streams; com
a-1	*B. sarothroides* Broom baccharis	Comp	W, plants broom-like, moist sites, leaves toothed; com
u	*Bebbia juncea* Rush bebbia	Comp	Y, few flowered (all terminal) rush-like branches; uncom
a	*Berberis haematocarpa* Red mahomia	Berb	Y, wood and innerbark yellow, EG, spring; com
e	*B. repens* Creeping mahonia	Berb	Y, above ground stems short, spreading rootstocks, higher elevations; com

Shrubs—Continued

Species abbr.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
Brca-3	*Brickellia californica* California brickellia	Comp	W, deciduous, herb-like; com
Caer	*Calliandra eriophylla* Falsemesquite	Legu Mimos	P, W, straggling shrub resembling m quite but much smaller and witho spines; com
Caho	*Canotia holacantha* Canotia	Cela	Leaves small, spine tipped, deciduo scales, rush-like branches, yellow gre bark; uncom
Cabi	*Carphochaete bigelovii*	Comp	Pu, low branching shrub; uncom
Cebe-1	*Cercocarpus betuloides* Birchleaf mountainmahognny	Rosa	Y sepals, no petals, EG, leaves oval wi rounded apex, wedge-shaped tee finely toothed above the middle, d green above, grayish and slightly ha beneath; com
Cebr[1]	*C. breviflorus* Wright mountainmahogany	Rosa	Y sepals, no petals, EG, leaves obov or reverse lance shaped, a few round teeth near apex, hairless or sligh hairy above and pale and finely ha beneath; com
Cefe	*Ceanothus fendleri* Fendler ceanothus	Rham	W, spiny, leaves pubescent below, E com
Cegr	*C. greggii* Desert ceanothus	Rham	W, leaves grayish, twigs stiff, spineli EG; com
Cein-1	*C. integerrimus* Deerbrush ceanothus	Rham	W, leaves pale beneath, bright gre above, twigs limber, EG; com
Cepa-2	*Celtis pallida* Spiny hackberry	Ulma	G, along ephemeral streams, spi large shrub; com
Cere	*C. reticulata* Netleaf hackberry	Ulma	G, along ephemeral streams not spi warty bark, large shrub or small tr com
Ceoc	*Cephalanthus occidentalis* Common buttonbush	Rubi	W, wet sites, leaves large, opposite, whorls of 3, uncom
Chli	*Chilopsis linearis* Desertwillow	Bign	W streaked, tinged or spotted with large shrub or small tree along ephe eral streams; uncom

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[1] *Authors differ on whether the Arizona chaparral* Cercocarpus *species is* C. breviflorus *or* m tanus; *we believe it to be* breviflorus.

Shrubs—Continued

ecies br.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
a-3	*Colubrina californica* California colubrina	Rham	G, Y, subspinescent branches; uncom
	Condalia lycioides Southwestern condalia	Rham	W, numerous stout spines; com
ne	*Cowania mexicana* Cliffrose	Rosa	W, Y, twigs hairy, glandular, EG, leaves white, hairy beneath; uncom
i	*Crossosoma bigelovii* Bigelow crossosoma	Cros	W, rough bark; uncom
vh	*Dasylirion wheeleri* Wheeler sotol	Lili	W, EG, leaves rigid with sharp curbed spines; com
i	*Dodonaea viscosa* Clammy hopseedbush	Sapi	Y, foliage sticky; uncom
a	*Encelia farinosa* White brittlebush	Comp	Y, stems brittle, leaves hairy, gray, EG, transition drier sites; uncom
r	*E. frutescens* Bush encelia	Comp	Y, stems brittle, leaves not hairy, EG, transition drier sites; uncom
i	*Ephedra viridis* Green ephedra	Ephe	Leaves scales, EG; uncom
n-2	*Eriodictyon angustifolium* Narrowleaf yerba santa	Hydr	Li, W, leaves resinous above, hairy below, sprouts from roots as much as 2 or more meters from plant, especially following fire or other disturbance; loc dom
a	*Fallugia paradoxa* Apacheplume	Rosa	W, white bark, EG, leaves green above, rusty below; loc dom
u-2	*Fendlera rupicola* Cliff fendlerbush	Saxi	W or tinged with PU; bark-ridged, leaves scurfey; com
vi	*Ferocactus wislizeni* Southwest barrelcactus	Cact	Y, EG, flowers funnelform; uncom
ne †	*Forestiera neomexicana* New Mexican forestiera	Olea	Anthers Y, much branched giving tangled look; uncom
p-2	*Fouquieria splendens* Ocotillo	Fouq	R, appears leafless, tall spindly, thorny whiplike unbranched stems, transition drier sites; uncom

Shrubs—Continued

Species abbr.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
Fram †	*Franseria ambrosioides* Ambrosia bursage	Comp	Cr, EG, fruit with hook-tipped sp ; transition drier sites; uncom
Frca	*Fremontia californica* California fremontia	Ster	Y, EG; uncom
Gafl	*Garrya flavescens* Yellowleaf silktassel	Garr	No petals, grayish-green bark d leaves, EG, stems 4-angled; loc do
Gawr-2	*G. wrightii* Wright silktassel	Garr	No petals, EG, stems 4-angled, le s bright green; com
Goth	*Gossypium thurberi* Thurber cotton	Malv	W, branchlets quadrangular; unco
Hico	*Hibiscus coulteri* Desert rosemallow	Malv	Y with R basal spot, half shrub or sh ; uncom
Hodu	*Holodiscus dumosus* Rush rockspirea	Rosa	W, Cr, aromatic foliage, young t s hairy, older bark gray brown; unc
Hone	*Horsfordia newberryi* Newberry horsfordia	Malv	Y, yellow pubescence; uncom
Hymo	*Hymenoclea mongyra* Singlewhorl burrobrush	Comp	Uncom
Krpa	*Krameria parvifolia* Littleleaf krameria	Legu Caesa	Pu, herbage grayish, pubescent, t parasite; com
Latr	*Larrea tridentata* Coville creosotebush	Zygo	Y, EG, transition drier sites; unco
Loin-1	*Lonicera interrupta* Chapparral honeysuckle	Capr	W, Y, stems trailing or climbing;
Lyan	*Lycium andersonii* Anderson wolfberry	Sola	La, P, plant spiny, fruit a scarlet b ; com
Lyex	*L. exsertum* Desert wolfberry	Sola	La, plant spiny, leaves glandu , pubescent, fruit a scarlet berry; co
Lyfr	*L. fremontii* Fremont wolfberry	Sola	Pu, top growth very spiny, brittle, fr a scarlet berry; com
MAMM	*Mammillaria spp.* Fishhook or pincushion cacti	Cact	P, Y, PW, have crossing rows of ni - like knobs; uncom
Mibi-3	*Mimosa biuncifera* Catclaw mimosa (wait-a-minute bush)	Legu Mimos	P, W, spines wide, flat at base, recu d, mostly in pairs at the nodes, trans n drier sites; uncom

Shrubs—Continued

cies br.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
l	*Nicotiana glauca* Tree tobacco	Sola	Y, flowers tubular, funnel form; uncom
ni	*Nolina microcarpa* Sachuista	Lili	W, Cr, EG, leaves lax, resembles coarse grass; com
ac	*Opuntia acanthocarpa* Buckhorn cholla	Cact	R, Y, EG, efect plant, spines covered with a loose papery sheath, stems (joints) round; com
ar	*O. arbuscula*	Cact	R, delicate cactus; uncom
bi	*O. bigelovii* Arizona jumping pricklypear	Cact	GY, EG, spines with a loose papery sheath, stems (joints) round; com
ch	*O. chlorotica* Dollarjoint pricklypear	Cact	Y, low spreading plant, main spines yellow transluscent stems (joints) yellowish and flattened distinct trunk; uncom
en †	*O. engelmannii* Engelmann pricklypear	Cact	Y, EG, stems (joints) flattened, low spreading plant; com
fu	*O. fulgida* Sonora jumping cholla	Cact	P, W, streaks of La, erect plant, stems (joints) round, EG, appears straw colored because of numerous spines; uncom
le	*O. leptocaulis* Tesajo	Cact	BrY, EG, stems (joints) round, erect plant, spines enveloped with a loose paper sheath; uncom
ph	*O. phaeacantha* Brown spine pricklypear	Cact	Y, EG, prostrate or decumbent, stems (joints) flat, gray green, spines not sheathed; uncom
sp	*O. spinosior* Cane cholla	Cact	Y, R, W, P, fruits pear-shaped; erect plant, stems (joints) round; com
in-2	*Parthenocissus inserta* Thicket creeper	Vita	G, stems climbing or trailing, adhering discs on tendril tips; com
mi-2	*Penstemon microphyllus* Littleleaf penstemon	Scro	SY, flowers tubular, EG; uncom
mi	*Philadelphus microphyllus* Littleleaf mockorange	Saxi	W, exfoliating bark; uncom

Shrubs—Continued

Species abbr.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
Phte	*Phlox tenuifolia* Vine phlox	Pole	Cr, in shade, climbing, leaves s se; com
Plse †	*Pluchea sericea* Arrowweed pluchea	Comp	Pu, rank smell, silky pubescent t lar flower; uncom
Prsev	*Prunus serotina* subsp. *virens* Southwestern chokecherry	Rosa	W, semi-evergreen, attains tree s in moist situations, young bark gla lar punctate; com
Ptan-1	*Ptelea angustifolia* Narrowleaf hoptree	Ruta	GY. unpleasant odor, twig bark l wn or dark purple; com
Quch	*Quercus chrysolepis* Canyon live oak	Faga	Small tree, leaves entire to very s es-cent; uncom
Quchp	*Q. chrysolepis* var. *palmeri* Palmer oak	Faga	Shrub or small tree, golden tome m on cup at base of acorns, leave n-dulate, very prickly; com
Qutu	*Q. turbinella* Shrub live oak	Faga	EG, upper leaf surfaces dull, yell or whitish, resinous undersides; do
Rhca	*Rhamnus californica* California buckthorn	Rham	G, EG, fruits black, has bud sc s; uncom
Rhcr	*R. crocea* Hollyleaf buckthorn	Rham	YG, EG, fruits red, no bud scales;
Rhgl	*Rhus glabra* Smooth sumac	Anac	Leaves turn bright red in fall, EG h soil, uncom
Rhov	*R. ovata* Sugar sumac	Anac	Cr, EG, old bark very shaggy, fruits l; com
Rhra †	*R. radicans* Poison ivy	Anac	GW, deciduous, often climbing st , fruits yellowish white; uncom
Rhtr	*R. trilobata* Scunkbush sumac	Anac	Y, deciduous, leaves three lobed bright red in fall; com
Ruar	*Rubus arizonensis*	Rosa	W tinged with P, prostrate (flowe branches erect), bark smooth, pric ; uncom
Rune	*R. neomexicanus* New Mexican raspberry	Rosa	W tinged with P, not prickly, bark fl ; uncom
Sabe	*Salix bebbiana* Bebb willow	Sali	Upper surface of leaves pubesc streamsides; uncom

Shrubs—Continued

ecies bbr.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
h	*Simmondsia chinensis* California jojoba	Buxa	Y sepals (no petals), EG, stems brittle. Transition drier sites; uncom
MP	*Symphoricarpos sp.* Snowberry	Capr	P, W, fruits snow white, low spreading shrub, older bark exfoliating, higher elevations, often codominant under Gambel oak; uncom
el	*Solanum elaeagnifolium* Silverleaf nightshade	Sola	Pu, prickly leaves and stems, plant grayish; uncom
fe	*S. fendleri* Fendler potato	Sola	Pu, small potato-like tubers, moist sites; uncom
a-2	*Trixis californica* American trixis	Comp	Y, leaves glandular on lower surfaces; uncom
ca	*Vauquelinia californica* Torrey vauquelinia	Rosa	W, EG; uncom
ar	*Vitis arizonica* Canyon grape	Vita	Stems climbing, along streams, large heart-shaped leaves; uncom
ba	*Yucca baccata* Datil yucca	Lili	W, EG, fruit banana shaped; com
el	*Y. elata* Soaptree yucca	Lili	W, EG, has a distinct trunk, scapose flower stalk; uncom

Trees

Species abbr.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
Acco	*Acacia constricta* Mescat acacia	Legu Mimos	OY, thorns straight, slender, whi uncom
Acgr	*Acer grandidentatum* Bigtooth maple	Acer	GY, leaves three lobed with sawtooth edges, twigs reddish brown; com
Alob	*Alnus oblongifolia* Arizona alder	Betu	Grayish brown, scaly bark on ol trunks, leaves elliptic, sawtooth edges; uncom
Cagi	*Carnegiea gigantea* Saguaro	Cact	Tree-like cactus, EG, transition des shrub to chaparral; uncom
Cefl	*Cercidium floridum* Blue paloverde	Legu Caesa	Y, ends of leafy branches not stron spine-tipped, bark green, along wash transition desert shrub to chaparr uncom
Cemi	*C. microphyllum* Littleleaf paloverde	Legu Caesa	Y, ends of leafy branches spine-tipp bark green, transition desert shrub chaparral; uncom
Cuar	*Cupressus arizonica* Arizona cypress	Cupr	EG, cones gray, cone scales with a poi in center; loc dom
Fran-2	*Fraxinus anomala* Single leaf ash	Olea	Y, G, 1 or 3 leaflets per leaf; uncom
Franl	*F. anomala* var. *lowelli* Lowell ash	Olea	Y, G (hairy), 2 or 3 leaflets per leaf, alo streams; com
Frve	*F. velutina* Velvet ash	Olea	Y, G, 5 to 9 leaflets per leaf; uncom
Juma	*Juglans major* Arizona walnut	Jugl	Leaves red in autumn, strongly scent 9 to 13 leaflets per leaf; com
Jude	*Juniperus deppeana* Alligator juniper	Cupr	Monecious, bark checkered, tru branching a few feet above ground le leaves resinous, berry mealy, bluish brownish maturing the second year, 3 4 seeded; com
Jumo	*J. monosperma* One seeded juniper	Cupr	Dioecious, bark fibrous, branching ground level, berry succulent, d blue, maturing in one year, one seed (or occasionally 2); com

Trees—Continued

S cies br.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
Ju	*J. osteosperma* Utah juniper	Cupr	Monecious, bark fibrous, branching several feet above ground level, berry mealy, brownish, maturing the second year, 1 or 2 seeded; com
M .i	*Morus microphylla* Texas mulberry	Mora	G, along streams, leaves dark green above and paler and hairy below; uncom
Pi	*Pinus edulis* Pinyon	Pina	EG conifer, 2 needles per leaf bundle or sometimes single, higher elevations; uncom
Pi	*P. ponderosa* Ponderosa pine	Pina	EG conifer, 3 needles per leaf bundle, higher elevations; uncom
Pl	*Platanus wrightii* Arizona sycamore	Plat	Along streams, outer bark flakes off exposing white inner bark, large palmately lobed leaves; com
P 2	*Populus fremontii* Fremont cottonwood	Sali	Along streams, cottony seeds, bark gray, thick and deeply furrowed; uncom
P 1	*P. tremuloides* Quaking aspen	Sali	Moist sites, higher elevations, bark white, leaves golden or orange in autumn; uncom
P	*Prosopis velutina* Velvet mesquite	Legu Mimos	Y, along streams, branches spreading, straight spines in pairs, pods sweet; uncom
P 3	*Pseudotsuga menziesii* Common Douglas fir	Pina	EG conifer, needles arise singly, short stalked and flat, higher elevation transition; uncom
Q	*Quercus arizonica* Arizona white oak	Faga	EG, leaves rounded or cordate at base, dull blue-green above, densely hairy below with prominent veins, bark light gray or whitish; dom
Q n	*Q. emoryi* Emory oak	Faga	EG, leaves lance shaped with a spiny point, shiny yellow green on both sides, cordate at base, with small tuft of tonentum on both sides of base of midrib on lower side of leaf, bark dark gray to black; dom
Q 1	*Q. gambelii* Gambel oak	Faga	Only deciduous oak in Arizona chaparral, locally dominant of small acreages on north slopes; loc dom

Trees—Continued

Species abbr.	Scientific and common name	Family/ subfamily	Flower color, distinguishing characteristics and relative abundance
Rone-1	*Robinia neomexicana* New Mexican locust	Legu Papil	PuP, spines in pairs, 15 to 21 lea bristle tipped; uncom
Sago	*Salix goodingii* Gooding willow	Sali	Along streams, leaves green or yel green on both sides; uncom
Sala-1	*S. laevigata* Red willow	Sali	Lower leaf surfaces paler than up uncom
Same-1	*Sambucus mexicana* Mexican elder	Capr	YW, along streams, pith makes up m than one-half the diameter of twigs, dark blue berries with a bloom; unc
Sasa	*Sapindus saponaria* Soapberry	Sapi	Along streams, fruits berry-like, yell translucent; uncom
Tape †*	*Tamarix pentandra* Fivestamen tamarisk (Salt cedar)	Tama	Along streams, forms thickets al drainages; uncom

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Appendix 1

Grass tribes and the page number in Hitchcock (1950) where the tribe key begins

Abbreviation	Tribe	Page
Agr	Agrostideae	313
And	Andropogoneae	737
Ave	Aveneae	280
Chl	Chlorideae	491
Fes	Festuceae	31
Hor	Hordeae	230
Pan	Paniceae	569
Pha	Phalarideae	547
Zoy	Zoysieae	482

Appendix 2

amilies of grasslike plants, forbs, half-shrubs, and trees and page number in Kearney and Peebles (1960) where family key begins (subfamilies of legumes listed immediately below family name)

Abbreviation	Scientific name	Page
Acer	Aceraceae	526
Aizo	Aizoaceae	280
Amara	Amaranthaceae	264
Amary	Amaryllidaceae	191
Apoc	Apocynaceae	651
Aris	Aristolochiaceae	227
Ascl	Asclepiadaceae	655
Berb	Berberidaceae	320
Bora	Boraginaceae	707
Cact	Cactaceae	567
Camp	Campanulaceae	829
Capp	Capparidaceae	355
Capr	Caprifoliaceae	812
Cary	Caryophyllaceae	291
Chen	Chenopodiaceae	249
Comm	Commelinaceae	166
Comp	Compositae	829
Conv	Convolvulaceae	666
Corn	Cornaceae	624
Cras	Crassulaceae	358
Cruc	Cruciferae	325
Cucu	Cucurbitaceae	820
Cupr	Cupressaceae	57
Cusc	Cuscutaceae (see Convolvulaceae)[1]	666
Cype	Cyperaceae	145
Euph	Euphorbiaceae	501
Faga	Fagaceae	215
Fouq	Fouquieriaceae	639
Gera	Geraniaceae	484
Hydr	Hydrophyllaceae	696
Jugl	Juglandaceae	213
Junc	Juncaceae	168
Labi	Labiatae	731

[1] *Kearney and Peebles do not recognize Arizona species in the Cuscutaceae family but recent changes place certain of our species in this family (Lawrence 1958).*

Appendix 2—Continued

Abbreviation	Scientific name	Page
Legu	Leguminosae	395
Caesa	Caesalpinioideae	403
Mimos	Mimosoideae	395
Papil	Papillionoideae	409
Lili	Liliaceae	174
Lina	Linaceae	488
Loas	Loasaceae	562
Lyth	Lythraceae	587
Malp	Malpighiaceae	497
Malv	Malvaceae	536
Mart	Martyniaceae	795
Nyct	Nyctaginaceae	270
Olea	Oleaceae	640
Onag	Onagraceae	589
Orob	Orobanchaceae	796
Oxal	Oxalidaceae	487
Papa	Papaveraceae	322
Pina	Pinaceae	50
Plan	Plantaginaceae	802
Plat	Platanaceae	371
Pole	Polemoniaceae	678
Polyg-1	Polygalaceae	497
Polyg	Polygonaceae	228
Polyp	Polypodiaceae	34
Port	Portulaceae	285
Ranu	Ranunculaceae	304
Rham	Rhamnaceae	529
Rosa	Rosaceae	372
Rubi	Rubiaceae	805
Ruta	Rutaceae	493
Sali	Salicaceae	207
Sant	Santalaceae	226
Saxi	Saxifragaceae	361
Scro	Scrophulariaceae	761
Sela	Selaginellaceae	28
Sola	Solanaceae	748
Ster	Sterculiaceae	554
Tama	Tamaricaceae	557
Typh	Typhaceae	63
Umbe	Umbelliferae	606
Urti	Urticaceae	222
Vale	Valerianaceae	818
Verb	Verbinaceae	724
Vita	Vitaceae	534
Zygo	Zygophyllaceae	489

Appendix 3

Color and other abbreviations[1]

	Apricot	O	Orange
	Blue	Or	Orchid
	Brown	P	Pink
	Bronze	Pu	Purple
	Copper	R	Red
	Cream	Ro	Rose
	Crimson	S	Sulfur
	Canary yellow	Sc	Scarlet
	Evergreen	St	Straw
	Green	SY	Sulfur yellow
	Grenadine red	V	Violet
	Lavender	W	White, whitish
	Lilac	WP	Without petals
	Magenta	Y	Yellow
a	Maroon		

[1] *Color abbreviations may be combined: GBr = greenish brown; Pu = rose-purple, etc.*

Appendix 4

Glossary

ulbous: Possessing bulbs or bulblets.

audex: The combined stem and root, applied often to the thickened basal parts of stems.

onnate: Similar parts united, at least at base.

ordate: Heart-shaped, as in leaves with indented base.

yme: A (usually broad and flattened) inflorescence with flowers opening successively from the center outward.

ecumbent: Reclining, then ascending.

laccid: Flabby, limp, lax.

land: A secreting structure, either borne on the surface (glandular hairs, etc.) or imbedded in the tissues, as are many oil glands.

erb: A plant that is not woody, or not woody above ground.

ispid: Roughly hirsute or bristly.

ucilaginous: Moist and sticky, like mucilage.

btuse: With the end rounded or blunt.

dd-pinnate: Pinnate with a single terminal leaflet.

vate: Flat, but having the outline of an egg and broadest below the middle.

almate: Lobed or veined outwardly from the base, like the fingers of a hand.

Pectinate: Comblike, having narrow, closely set teeth or divisions.

Appendix 4—Continued

Pedicel: The stalk of a single flower, or, in *Compositae*, an ultimat branch of an inflorescence, bearing a head.

Perfoliate: Referring to a leaf with base surrounding the stem, s that the stem apparently passes through it.

Petiole: The foot stalk of a leaf.

Pilose: Hairy, with distinct, soft, more or less spreading hairs.

Pinnate: Applied to a compound leaf when the leaflets are arrange along the rachis or stalk; and to veins when branching from alon the midrib (feather-veined).

Pinnatifid: Pinnately cleft, the clefts not extending to the midrib.

Plumose: Feathered with fine hairs, as often the awns of grasses and the pappus bristles of *Compositae*.

Prickle: A more or less rigid, often hooked outgrowth of the bark or subepidermal tissue.

Prostrate: Flat on the ground.

Puberulous: Fine or minute pubescence.

Pubescent: Hairy or downy.

Scape, scapose, scorpioid: A peduncle or a flowerbearing stem, leafless or with leaves reduced to bracts, arising from the ground.

Sepal: One of the segments of the calyx or outer envelope of the flower.

Sessile: Not stalked, without a petiole, pedicel, or stripe.

Shrub: A woody plant, smaller than a tree and several-stemmed, without a trunk.

Spine: Sharp-pointed modified leaf or leaf part(s).

Strigose: Bearing stiff, straight, appressed hairs.

Succulent: Fleshy, thick and juicy.

Symbiotic: Descriptive of situations where two individuals live intimately together to their mutual benefit.

Tendril: A slender organ, a modified leaf or branch, by means of which plants support themselves on other plants or on various objects.

Terete: Cylindric, with a circular cross section, not angled.

Terminal: At the summit or apex.

Thorn: A shortened and hardened, sharp-pointed branch.

Tomentose: A covering of soft, matted hairs.

Trailing: Lying on the ground, but not rooting at the nodes.

Translucent: Nearly transparent.

Tree: A large, woody plant with an evident trunk below the branches.

Villous: Pubescent, with long and weak but not matted hairs; long-pilose.

Viscid: Sticky.

Winter annual: A plant germinating in autumn and flowering or fruiting the following spring.

Appendix 5

Definitions of relative abundance designations.

om., Dominant: Occurs as a dominant or codominant on extensive acreages throughout the type, such as *Cercocarpus* spp. and *Quercus turbinella*.

)c. Dom., Locally Dominant: Occurs as a dominant or codominant on limited acreages throughout the type, such as *Quercus gambelii* (mesic north slopes), *Eriogonum wrightii* (xeric sites), and *Fallugia paradoxa* (channel bottoms).

om., Common: Occurs over a large percentage of the type and may be (1) dense enough to exert an appreciable ecological influence in the community, such as *Bouteloua curtipendula* and *Rhus trilobata*, or (2) in general, scattered throughout the type but not dense enough to exert an appreciable ecological influence in the community, such as *Rhamnus crocea* and *Verbena wrightii*.

ncom., Uncommon: May be (1) present in very limited numbers throughout the type, such as *Sporobolous cryptandrus*, (2) prominent but limited to specific habitats, such as, *Salix* spp. (very mesic channel sites), *Acacias* spp., *Prosopis velutina*, *Simmondsia chinensis*, etc. which are desert shrub species prominent in the transition between desert shrub and chaparral, or (3) limited geographically, such as *Bromus trinii* (has been identified only on the west slope of Mingus Mountain).

Appendix 6

ʼire adaptation characteristics of important trees and shrubs of the Arizona chaparral.

Common name	Scientific name	Adaptation to fire
	Trees	
igator juniper	*Juniperus deppeana*	Sprouts from root crown
zona cypress	*Cupressus arizonica*	Seed cones opened
zona oak	*Quercus arizonica*	Sprouts from root crown
ıyon live oak	*Quercus chrysolepis*	Sprouts from root crown
ıory oak	*Quercus emoryi*	Sprouts from root crown
mbel oak	*Quercus gambelii*	Sprouts from root crown and roots
well ash	*Fraxinus anomala*	Sprouts from root crown
w Mexico locust	*Robinia neomexicana*	Sprouts from root crown
e seeded juniper	*Juniperus monosperma*	None
ıyon	*Pinus edulis*	None
nderosa pine	*Pinus ponderosa*	Thick bark provides considerable protection
ah juniper	*Juniperus osteosperma*	None

Appendix 6—Continued

Common name	Scientific name	Adaptation to fire
	Shrubs	
Baker serviceberry	*Amelanchier bakeri*	Sprouts from root crown
Birchleaf mountain-mahogany	*Cercocarpus betuloides*	Sprouts from root crown
California buckthorn	*Rhamnus californica*	Sprouts from root crown
Catclaw	*Acacia greggii*	Sprouts from root crown
Catclaw mimosa	*Mimosa biuncifera*	Sprouts from root crown
Datil yucca	*Yucca baccata*	Weak sprouter
Deerbrush ceanothus	*Ceanothus integerrimus*	Sprouts from root crown
Desert ceanothus	*Ceanothus greggii*	Weak sprouter; reproduces prolifically from seed following fire, germination stimulated by fire.
Snowberry	*Symphoricarpos sp.*	Sprouts from root crown
Hairy mountain-mahogany	*Cercocarpus breviflorus*	Sprouts from root crown
Engelmann pricklypear	*Opuntia phaeacantha* var. *discata*	None
Falsemesquite	*Calliandra eriophylla*	Sprouts from root crown
Hollyleaf buckthorn	*Rhamnus crocea*	Sprouts from root crown
Littleleaf krameria	*Krameria parvifolia*	Sprouts from root crown
Netleaf hackberry	*Celtis reticulata*	Sprouts from root crown
Palmer oak	*Quercus chrysolepis* var. *palmeri*	Sprouts from root crown
Parry agave	*Agave parryi*	None
Pointleaf manzanita	*Arctostaphylos pungens*	Reproduces prolifically from seeds which require heat scarificatio to germinate.
Pringle manzanita	*Arctostaphylos pringlei*	Like pointleaf manzanit
Redberry algerita	*Berberis haematocarpa*	Sprouts from root crown
Sacahuista (bear-grass	*Nolina microcarpa*	Sprouts from root stock
Shrub live oak	*Quercus turbinella*	Sprouts from root crown
Skunkbush	*Rhus trilobata*	Sprouts from root crown
Soaptree yucca	*Yucca elata*	None
Sugar sumac	*Rhus ovata*	Sprouts from root crown
Yellowleaf silktassel	*Garrya flavescens*	Sprouts from root crown
Wheeler sotol	*Dasyliron wheeleri*	None
Wright silktassel	*Garrya wrightii*	Sprouts from root crown
Yerba-de-pasmo	*Baccharis pteronioides*	Sprouts from root crown
Yerba santa	*Eriodictyon angustifolium*	Reproduces from seed and prolifically by sprouting from shallo lateral roots.

Appendix 7

S cies whose names have been changed since Kearney and Peebles (1960) and Hitchcock (1960) were published.

Grasses

Old name	New name
dropogon barbinodis	*Bothriochloa barbinodis*
cirratus	*Schizachyrium cirratum*
scoparius	*S. scoparius*
stuca octoflora	*Vulpia octoflora*
pacifica	*V. microstachys*
leria cristata	*K. nitida*
dens pilosus	*Erioneuron pilosus*
pulchellus	*E. pulchellus*

Forbs and Grasslike Plants

Old name	New name
clepias capricornu	*A. asperula*
ter bigelovii	*Machaeranthera bigelovii*
tagetinus	*M. tagetinus*
tanacetifolius	*M. tanacetifolius*
eria chrysostoma	*Lasthenia chrysostoma*
nopholis mexicana	*C. alpina* var. *mexicana*
tura meteloides	*D. wrightii*
geron canadensis	*Conyza canadensis*
nseria confertiflora	*Ambrosia confertiflora*
ia aggregata	*Ipomopsis aggregata*
pplopappus cuneatus	*Ericameria cuneatus* var. *spatulata*
gracilis	*Machaeranthera gracilis*
terotheca subaxillaris	*Chrysopsis psammophila*
ffmanseggia densiflora	*H. glauca*
ntzelia pumila	*M. multiflora*
ybaphus coccinea	*Mirabilis coccinea*
linearis	*M. linearis*
pumilus	*Allionia pumila*
laea longimucronata	*P. truncata*
ezia nana	*Acourtia nana*
wrightii	*A. wrightii*
ntago purshii	*Plantago pategonica* var. *purshii*
sola kali	*S. iberica*
laspi fendleri	*Thlaspi montanum* var. *fendleri*
gia nepetaefolia	*T. ramosa*
cia exigua	*V. ludoriciana*
nthium saccharatum	*X. strumarium*

Appendix 7—Continued

Half shrubs

Old name	New name
Aplopappus cuneatus	*Ericameria cuneatus* var. *epatulata*
A. heterophyllus	*Isocoma wrightii*
A. laricifolius	*Ericameria laricifolius*
A. spinulosus	*Machaeranthera pennatifida*
Dalea parryi	*Marina parryi*
Franseria deltoidea	*Ambrosia deltoidea*
Gutierrezia sarothrae	*Xanthocephalum sarothrae*
Senecio longilobus	*S. douglasii* var. *longilobus*
S. monoensis	*S. douglasii* var. *douglasii*

Shrubs

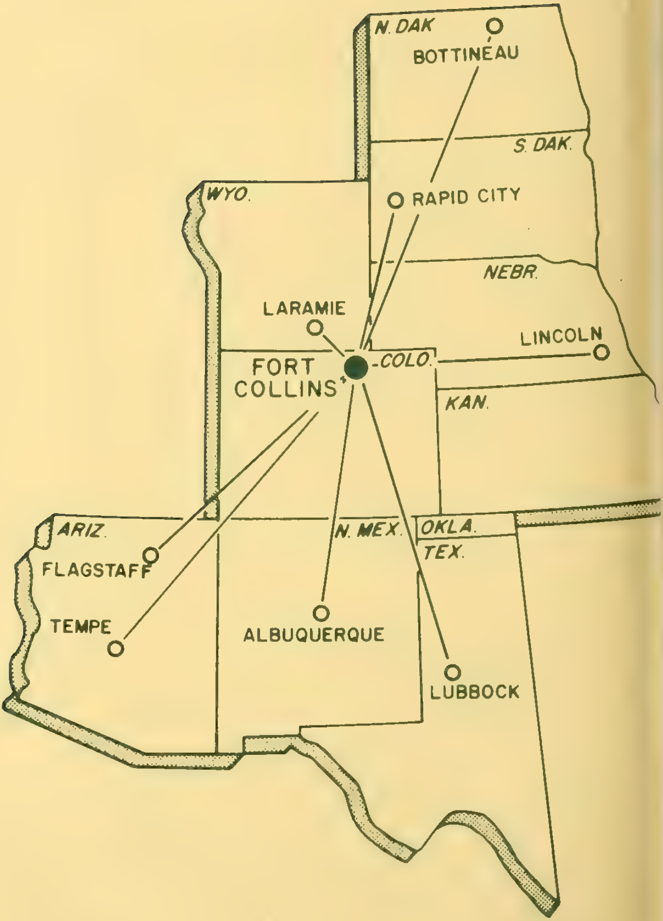
Old name	New name
Baccharis glutinosa	*B. salicifolia*
Ferocactus wislezeni	*F. acanthodes*
Franseria ambrosioides	*Ambrosia ambrosioides*
Opuntia engelmannii	*O. phaeacantha* var. *discata*
Pluchea sericea	*Tessaria sericea*
Rhus radicans	*Toxicodendron radicans*

Trees

Old name	New name
Fraxinus lowellii	*Fraxinus anomala* var. *lowellii*
Quercus palmeri	*Q. chrysolepis* var. *palmeri*
Tamarix pentandra	*Tamarix chinensis*

Knipe, O. D., C. P. Pase, and R. S. Carmichael. 1979. Plant species of the Arizona chaparral. USDA For. Serv. Gen. Tech. Rep. RM-64, 54 p. Rocky Mt. For. and Exp. Stn., Fort Collins, Colo.

Lists the associations within the chaparral type, and the species that have been identified in the type, including scientific names, common names, duration, and relative abundance. As an aid to identification, family names are given as are distinguishing characteristics such as flower color, specific habitat requirements, unusual growth characteristics, etc. The species are listed according to growth form: grasses, forbs and grasslikes, half shrubs, shrubs, and trees.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A National Workshop on Mitigating Losses of Fish and Wildlife Habitats

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Acknowledgements

The Mitigation Symposium was the product of close cooperation between many conservation agencies and private organizations. They were exceedingly generous in permitting their representatives to attend the many planning meetings, and many of them, as listed below, contributed financially to the support of the Symposium or publication of the Proceedings.

Special credit is due to William C. Melander and John C. Peters, both environmental specialists with the Bureau of Reclamation, who spent uncounted hours for over two years, from the birth of the idea through the planning, promotion, and implementation, and who, in the last few months, worked with the Program Director on almost a daily basis.

Thanks are due also to the chairpersons and cochairpersons of the sessions, who not only shaped and coordinated the programs within their own sessions, but developed and presented recommendations at the final plenary session. Dr. Laurence R. Jahn tackled the formidable task of developing from the entire Symposium the series of recommendations included in the Proceedings, and distributed in advance to decision makers.

We thank the Rocky Mountain Forest and Range Experiment Station, particularly its staff members Robert H. Hamre and Robert P. Winokur, for contributing their expertise and agreeing to handle publication and distribution of the Proceedings. The authors of both invited and contributed papers have earned our thanks for submitting their camera-ready manuscripts to expedite publication of these Proceedings. Each contributor is responsible for the accuracy and style of his or her paper. Statements of contributors may not necessarily reflect the policies of the U.S. Department of Agriculture.

The Colorado State University Office of Conferences and Institutes, through its representatives Caroline Frye and Craig Somers, handled graciously and effectively innumerable details concerned with the conduct of the Symposium itself, and the transportation, housing, feeding, registration, and general welfare of the participants. June Cringan, Symposium Secretary for over a year, was tremendously helpful throughout.

Elsewhere in the Proceedings are listed the names of the Steering and Program Committees, who contributed immeasurably.

Gustav A. Swanson, Program Director

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Preface:

Development of the Mitigation Symposium

For many years fish and wildlife conservationists have been deeply concerned about the losses of habitat which occur so often as a result of large federal development projects. The Fish and Wildlife Coordination Act was designed to minimize, or mitigate, such losses but it proved to be ineffective. The problem was frequently discussed at professional meetings, often with a sense of frustration and confusion.

How could these habitat losses and adverse impacts be avoided or mitigated more effectively? How serious was the problem? What was the effect of newer legislation, such as the National Environmental Protection Act and the Endangered Species Act? Were still more laws needed, or simply better enforcement of existing laws?

By early 1976 Bill Melander was convinced that a regional or national meeting devoted exclusively to the mitigation issue was needed, so in March and April of that year he began an extensive correspondence with his fishery biologist colleagues to learn their reaction. Almost without exception they agreed that such a conference or workshop was desirable and a Steering Committee was formed, with Bill as its chairman, by unanimous consent.

The first meetings of the Steering Committee were held March 1 and September 14, 1977, and minutes distributed to several hundred offices and officials at the expense of the Western Division of the American Fisheries Society. The parent AFS also gave Bill strong support, urged that it be a national rather than a regional meeting, and agreed early to act as a sponsoring organization. John Peters was willing to serve as Finance Chairman, and to work with Bill Melander in selecting a time, place, and program director. They persuaded Gus Swanson to undertake the Program Director responsibilities. A well-attended meeting of the Steering Committee was held in March, 1978, at Phoenix, Arizona, at the North American Wildlife and Natural Resources Conference. The meeting agreed unanimously with the Melander and Peters recommendations, and selected a Program Committee to work with Gus Swanson. Other professional organizations were identified to invite as co-sponsors, and a list of potential speakers and session chairpersons developed.

The overall objectives of the Symposium were agreed to be:

A. To review the magnitude, and the seriousness of the losses of fish and wildlife habitat as a result of changing land and water use with particular emphasis on federal development projects,
B. To review the extent to which these habitat losses are being and have been mitigated, and
C. To develop strategies, and practical recommendations, for minimizing fish and wildlife habitat losses and achieving more effective mitigation.

Additional guidelines established by the Steering Committee were that:

a) The scope be nationwide, and diligent efforts be made toward getting all parts of the country well represented; Canadian participation should be encouraged.
b) We should work toward friendly relations and mutual understanding to develop cooperation between agencies which will result in improved mitigation. "Negative thinking or condemnation of past practices would not be sanctioned."
c) A plenary session of invited papers the first day presenting "The View from the Top" would be followed by a day and a half of specialized concurrent sessions of contributed papers and a final plenary session devoted to summary and recommendations.
d) Proceedings should be published as promptly as possible after the meeting.

Subsequent meetings dealt more with details than broad outlines. Bill Melander continued to promote interest in the Symposium. John Peters sought the needed financial support, and Gus Swanson worked virtually full-time for many months on the program.

The Symposium attracted 625 registrants from 46 states and 6 Canadian provinces, plus Guam and El Salvador. Requests for the Proceedings have come from throughout the U.S. and Canada, and many from abroad. Clearly it was a timely meeting on a subject of deep concern.

William C. Melander, and
Gustav A. Swanson.

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The Mitigation Problem: A Background Review for the Mitigation Symposium

Ann Rappoport [1]

Fish and wildlife habitat is continuously being destroyed or degraded in the United States and Canada by many types of developments. Sometimes such habitat losses are inevitable and little can be done to prevent or control them, but often they can, in the public interest, be avoided or mitigated.

Fish and wildlife are recognized as such an important public resource that there have been several official efforts to mitigate the adverse impacts to fish and wildlife habitat, but the results have been negligible, and generally inadequate. The need for a national conference to consider ways of improving the situation is obvious.

The act of Congress which deals most directly with the mitigation problem is the Fish and Wildlife Coordination Act (FWCA) first passed in 1934, then amended and strengthened in 1946 and most recently in 1958. It was intended to give consideration to fish and wildlife resources in the planning and construction of federal water development projects for irrigation, flood control, or hydroelectric power. There are numerous other federal laws which relate to mitigation of habitat impacts. These will be discussed in the Symposium by Department of Interior Solicitor Leo Krulitz. Examples include the National Environmental Policy Act (NEPA) of 1969, the Surface Mining Control and Reclamation Act of 1977, and numerous others.

However, most study of the subject, and most efforts to refine and improve mitigation have focused on water projects, and the FWCA, and this paper will do the same.

The term "mitigation" was first used in connection with wildlife in the FWCA. However, mitigation and the philosophy behind it have never been consistently or clearly defined by all agencies connected with its use. According to Webster's Dictionary, mitigation is "the act of mitigating, abatement or diminution of something painful, harsh, severe ... alleviation." This definition will be the foundation for the mitigation process discussed here.

The concepts of enhancement, compensation, and replacement are also bound up in fish and wildlife mitigation. Enhancement is the development and improvement of wildlife resources. Under the FWCA it is to be done in conjunction with mitigation. Enhancement will not be covered in detail here. Compensation and replacement, however, may be considered within the framework of mitigation. To mitigate is to reduce impacts. That reduction may be anywhere from 1 to 100 percent. Full compensation equals the 100 percent reduction of losses. Replacement could also be from 1 to 100 percent but it implies a tradeoff whereby lost wildlife and their habitats are "replaced" with other type(s) of wildlife habitat.

Past Efforts to Improve Fish and Wildlife Mitigation

In the past decade the FWCA has come under extensive criticism for not providing fish and wildlife the protection it promised. Subsequent efforts to strengthen or further regulate Coordination Act implementation have been partially successful. Passage of the NEPA in 1969 gave all government agencies, in addition to private citizens, opportunity for greater involvement in the development of all federal projects, or private projects which involved federal land or funds.

The first organized, multi-interest effort to improve fish and wildlife coordination produced the 1971 "Action Report--Conservation and enhancement of fish and wildlife in the national water resources program" (U.S. Bureau of Sport Fisheries and Wildlife et al. 1971). This report was the outcome of four regional workshops and a national symposium, involving 238 individuals with federal, state, and private conservation organizations. The Action Report included 169 recommendations for amendments and new legislation, policies, procedures, and financing. As a consequence of this report, a National Coordinating Committee was formed to monitor adoption of the recommendations; various amendments to the FWCA were introduced in subsequent Congresses (U.S. House of Representatives 1974).

The House Subcommittee on Fisheries and Wildlife Conservation and the Environment subsequently requested an evaluation of Coordination Act implementation from the U.S. General Accounting Office (GAO). GAO's March

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1974 report was the basis for 4 days of hearings on the Act and several bills to amend it (U.S. House of Representatives 1974). The record from those hearings documented numerous other cases which supported GAO's findings of "significant and numerous breakdowns in the coordination process" and conclusion that "wildlife conservation had not been considered equally with other features" of the water developments studied (U.S. General Accounting Office 1974:2). Numerous conservation groups, 33 state governors, and the directors of 16 state fish and game agencies or commissions submitted statements in support of legislatively strengthening the Act. Among these statements were ones from Jimmy Carter as governor of Georgia, Cecil Andrus as governor of Idaho, and Robert Herbst as Commissioner of the Minnesota Department of Natural Resources (U.S. House of Representatives 1974:145-147, 165). Although no bills to amend the FWCA were brought to the floor of Congress in 1974, interest in amending or otherwise improving the Act has not dropped.

Two related activities have been supported by the federal Administration and environmental community. The first of these was the National Wildlife Federation's (NWF) July 1977 petition to the Secretary of the Interior, Secretary of the Army, and Chairman of the Council on Environmental Quality to promulgate regulations to implement the FWCA (National Wildlife Federation 1977). The National Wildlife Federation (1977) urged (1) responsible federal agencies to review, up-date, and implement mitigation for the fish and wildlife impacts of all currently authorized water resource projects; (2) CEQ, the Corps of Engineers, and Department of Interior to develop regulations for determining fish and wildlife impacts and appropriate mitigation; USFWS Habitat Evaluation Procedures were cited as the best available technology; (3) inclusion of mitigation plans in draft EIS's as well as availability of such plans for public and agency review and comment; (4) concurrent funding and implementation of mitigation with project construction; and (5) better accounting of fish and wildlife impacts and necessary mitigation in permit issuing procedures.

The second activity related to improving the Coordination Act was the council on Environmental Quality's analysis of wildlife law (Council on Environmental Quality 1978). In draft form, the first two of CEQ's 26 recommendations from that analysis dealt with the FWCA (Council on Environmental Quality 1978). The first called for amending the FWCA to clarify and extend its coverage, as well as to assure timely and effective consideration of fish and wildlife impacts. Echoing the Federation's petition, the second recommendation was for procedural regulations to implement the Act.

In Congress, current efforts to amend the FWCA are being led by Congressman James L. Oberstar (D-Mn). As introduced in the 95th Congress, Congressman Oberstar's bill, H.R. 8161, to amend the Act, was developed with assistance of the Wildlife Management Institute, the National Wildlife Federation, and several involved U.S. Fish and Wildlife Service employees. Amendment of the FWCA failed during the 95th Congress because of: (1) lack of similar interest in the Senate; and (2) reluctance of the federal Administration to take a stand on the issue until announcement of the President's national water policy.

President's Water Policy Announcement of 1978

In announcing a national water policy in June, 1978, the President responded to both the National Wildlife Federation and Council on Environmental Quality by requiring the Department of the Interior to promulgate regulations for implementing the Coordination Act. Three other directives of that policy deal with mitigation funding and planning by mandating (1) demonstration of compliance with the FWCA in annual budget submissions to the Office of Management and Budget (OMB); (2) inclusion of funds required for all environmental mitigation in project construction appropriation requests; and (3) concurrent and proportional expenditures for mitigation and construction throughout project life.

The implications of these directives to fish and wildlife mitigations and amendment of the FWCA were both considered during the July 26, 27 and August 10, 1978 oversight hearings into administration of the FWCA (U.S. House of Representatives 1978). These hearings before the Subcommittee on Fisheries and Wildlife Conservation and the Environment, House of Representatives, Washington, D.C., produced testimony from 23 representatives of conservation organizations, local citizen groups, and forestry interests, as well as concerned reseachers, citizens, and state wildlife agencies. Spokespeople from the U.S. Fish and Wildlife Service, National Marine Fisheries Service, Bureau of Reclamation, Army Corps of Engineers, Council on Environment Quality, and Soil Conservation Service testified on agency problems and official policies. Written statements were received from the Tennessee Valley Authority in addition to 15 private citizen and conservation groups.

Witnesses from the conservation community and state agencies expressed broad support for improving the Coordination Act through regulation, the course of action urged by the President Although these witnesses generally agreed with the concepts of H.R. 8161, they and federal wildlife agency administrators advocated waiting for promulgation of regulations before continuing efforts to amend the FWCA. U.S. Fish and Wildlife Service Director Lynn Greenwalt and National Oceanic and Atmospheric Administrator Richard Frank also emphasized the severe understaffing and underfunding which have prevented them from fulfilling their responsibilities under the Coordination Act (Frank 1978, Greenwalt 1978). Administrators from federal construction agencies indicated satisfaction with the status quo, particularly from a legislative viewpoint (Haas 1978, Higginson 1989, Hill 1978).

Upon conclusion of the hearings, the prevailing concensus was in accord with the statement of the Council on Environmental Quality (CEQ) Chairman Charles Warren. He had conceded that once the regulations were developed, specific problems that must be handled legislatively might become apparent. The Subcommittee concurred with this view and decided to withhold further action on amending the Coordination Act. At present (March 1979) H.R. 8161 is being redrafted to complement the President's Water Policy and goal of simplifying governmental processes and paperwork. The redrafted bill will be reintroduced to the House by Congressman Oberstar and to the Senate, most likely by Senator John Chaffee (R-R.I.).

Eight Issues in Mitigation

The hearings focused attention on eight specific issues in the mitigation process: (1) an understanding of the mitigation concept itself; (2) evaluate criteria; (3) early planning; (4) implementation; (5) operation and maintenance; (6) follow-up; (7) funding; and (8) mitigation of already authorized projects. Early planning, implementation, operation and maintenance, and follow-up comprise the major parts of the mitigation process.

Defining Mitigation

Before mitigation of wildlife losses resulting from water resource projects can be effectively planned, implemented, or achieved, the involved parties must agree on the concept of mitigation itself (Clark and Banta 1978). Yet it was not until 1974 that the U.S. Fish and Wildlife Service (USFWS) defined mitigation in terms of the manner in which it should be accomplished (U.S. Fish and Wildlife Service 1974). Only last year did the Corps of Engineers issue a draft policy statement on measures they will recommend for mitigation (U.S. Corps of Engineers 1978). Lack of a common interpretation at the onset of the process virtually ensures later interagency difficulties as to what is necessary or justifiable mitigation.

Problems resulting from lack of a common definition were apparent during the 1978 oversight hearings into administration of the FWCA (U.S. House of Representatives 1978). There were numerous discrepancies between data supplied by the construction agencies and data provided by the wildlife agencies for those hearings. These data concerned money expended and lands acquired for wildlife mitigation as compared to project development. GAO found interpretational differences to be the prime cause of these discrepancies (U.S. General Accounting Office 1978). The agencies were not consistent in classifying measures as mitigation, enhancement, or only a normal project feature.

Evaluation Criteria for Pre-Development Evaluations and Determining Mitigation

No uniform system for arriving at mitigation recommendations has been agreed to by both construction and wildlife agencies. Nor is there agreement over criteria by which construction agencies justify acceptance, rejection, or modification of those recommendations.

Unless they accurately determine impacts of a proposed water project, wildlife agencies cannot develop suitable mitigation plans. Historically, fish and wildlife losses have been calculated in terms of numbers and species of animals expected to be affected by the project and in loss or gain of associated hunting and fishing recreation. Dollar values are assigned to these "use-day" calculations, then added to the benefit-cost ratio for the entire project. That ratio is a determining factor for Congressional authorization of proposed projects.

Benefit-cost accounting typically shows losses which may be compensated by the presence of a reservoir which produces high intensity recreation and access to formerly inaccessible areas. Hunting demand and use may increase while the wildlife resource base declines with loss of habitat.

Wildlife agencies have long been dissatisfied with traditional user-day methodology. Over the past 4 years the FWS has developed and refined a Habitat Evaluation Procedure (HEP) as an alternative to the terrestrial aspects of it. HEP is a means of quantifying non-economic values of wildlife resources by measuring project impacts and justifying mitigation requests on a biological basis of "habitat units". It focuses on resource quality, not only its use.

EARLY PLANNING

"Early Planning" is viewed by many as the key to minimizing or avoiding conflicts over development. This concept involves the earliest possible notification of federal and state wildlife agencies, as well as the public, whenever a development is contemplated. Active involvement of fish and wildlife interests throughout project planning and full consideration of their input are vital aspects of early planning. Nevertheless, interagency bargaining over mitigation, project design, and project operations takes place throughout project planning and development (Horak 1978).

One practice which could promote Congressional attention to the mitigation plan would be for wildlife agencies to appear with construction agencies before House and Senate authorization and appropriation committees. In that way Congress would be unable to ignore mitigation recommendations which are buried in project documents. Committees could ask questions of the agency with the appropriate technical expertise. Construction agencies would not be responsible for explaining recommendation or alternatives in which they have no interest.

The unavailability of funds for timely, thorough pre-development wildlife evaluations may be the most critical factor to effecting mitigation (Lollock 1978). If these studies are not made in the earliest stages of project development, wildlife agencies will be unable to develop valid recommendations for fish and wildlife mitigation. The longer such studies are delayed, the more difficult it becomes to modify project plans to meet project goals yet minimize impacts to wildlife.

IMPLEMENTING THE MITIGATION PLAN

Once accepted and/or modified, recommendations for mitigation must be coordinated with authorizations and appropriations for project development. Insufficient pre-development studies or various biological, logistical, and political constraints may then make it difficult, or even impossible, to implement accepted measures (Rappoport et al 1977, Jahn 1978).

The experience of the National Marine Fisheries Service with this stage of mitigation has been:

> When water development projects are built those features and operations designed for the protection of fish and wildlife resources and their habitats are not always implemented . . . . the intent of the FWCA is frustrated. We believe that it is important to establish the principle that FWCA-approved modifications should not be eliminated in the face of funding or other constraints without thorough, high-level consultation and review (Frank 1978:292-293).

OPERATING AND MAINTAINING IMPLEMENTED MITIGATION MEASURES

Operation and maintenance (O and M) of many mitigative project features is believed as crucial to minimizing wildlife losses as is initial implementation of the feature itself (Greenwalt 1978, Tripp 1978). Monitoring of streamflows is needed to ensure that agreed upon flows are maintained and adequate (Nelson et al 1976); habitat manipulations must be repeated every 5 or 10 years if desired productivities are to be sustained (Rappoport and Nagy 1979). But results of mitigative measures may be negated when development agencies refuse, local sponsors are reluctant, or state wildlife agencies are unable to fund O and M of those measures.

FOLLOW-UP STUDIES

Essential to scientific methodology or applications of prescriptive techniques is evaluating the outcome. If desired results were achieved, what factors are required to successfully repeat this process? If not what changes must be made? With no requirements or provisions for post-development evaluations in the FWCA and wildlife agencies finding themselves severely understaffed and underfunded, follow-up of project impacts or mitigation effectiveness has been a neglected aspect of the mitigation process (Lollock 1978, Zagata 1978).

FUNDING OF MITIGATION

Who funds each phase of the mitigation process can have as much influence on the success of mitigation as can the procedures and practices making up the process itself. The FWCA makes costs of planning, constructing, installing, and maintaining wildlife conservation measures an "integral part of the cost of water projects" (Sec. 662(d)). Because disputes over funding are often directly or indirectly related to problems in coordinating wildlife conservatio with project development, mitigation may be delayed or precluded at any of the four stages previously discussed (Frank 1978, Lollock 1978).

PROVIDING MITIGATION ON COMPLETED OR AUTHORIZED PROJECTS.

The possibility that future water developments will be environmentally sound and include appropriate fish and wildlife mitigations depends on three factors: (1) issuance of strong regulations for implementing the FWCA; (2) the President's support of only those water projects which satisfy his recently announced national criteria for approving such developments; and (3) Congressional adherence to those criteria in authorizing water projects. Yet the vast majority of potential water developments has already been authorized, many with incomplete or no fish and wildlife plans. Review and updating of mitigation planning has been largely ad hoc and in response to adversary proceedings (Parenteau 1978).

The record from oversight hearings into administration of the FWCA extensively documents the complexity and difficulty of fish and wildlife mitigations (U.S. House of Representatives 1978). This documentation confirms that no one group is responsible for failures in mitigating the fish and wildlife losses associated with water projects. Construction agencies are at fault for not always notifying wildlife agencies and the public of all project plans and for delaying mitigation; wildlife agencies are responsible for not always completing timely or thorough wildlife evaluations or mitigation plans; Congress is to blame for not providing adequate or timely funding for mitigation and for authorizing environmentally unsound water projects; and private citizens make mitigation impractical when they refuse to sell their lands for wildlife purposes. It is the purpose of this symposium to examine all facets of fish and wildlife mitigation and thus develop strategies for minimizing fish and wildlife habitat losses. Only through open exchanges and cooperation between all those involved in this subject will fish and wildlife mitigations become an effective and efficient part of natural resource developments.

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Ann Rappoport, currently with the Fish and Wildlife Service in Alaska, served for six months as a congressional intern with Representative James Oberstar (D.-Minn.) during the oversight hearings of July and August, 1978, on the Fish and Wildlife Coordination Act, and the need for amending it. She attended all of the hearings and prepared a draft summary of them for the Congressman and his staff, so much of the information in the foregoing essay was from the hearings. In addition, Ms. Rappoport's graduate studies at Colorado State University involved evaluation of mitigation on a series of western water projects.

Summary of the Symposium, and Recommendations for Improving Mitigation in the Future

Laurence R. Jahn[1]

It is a privilege and pleasure to be here to summarize the informative papers assembled for this workshop.

Speakers have focused firmly on the objectives for this meeting, namely (1) to review the magnitude and seriousness of habitat losses as a result of land and water uses, (2) to review the extent to which those habitat losses have been and are being mitigated, and (3) to develop strategies and practical recommendations for minimizing habitat losses and achieving more effective mitigation.

My purpose is to identify the heart of the issue, lay the ecological foundation for habitat mitigation and compensation, and provide background understanding for framing recommendations that can lead to improved common goals, policies and procedures.

THE HEART OF THE ISSUE

How can the legal mandates and procedures of construction agencies for irrigation, navigation, flood control and other purposes -- that have accumulated over time and in piecemeal fashion -- be molded to assure sustained functioning of aquatic and terrestrial systems, and the availability of common property resources, such as fish and wildlife? How can consumer needs be provided while avoiding and minimizing degradation and destruction of the landscape?

Changing uses of various units of the landscape are causing increasing concern, witnessed by the large attendance at this workshop. Some speakers have emphasized the need to maintain prime agricultural lands, with definition of such lands based on their soil capabilities, not present uses. In other words, trees currently growing on soils with potential capabilities for producing agricultural crops would be designated for those potential uses rather than current uses. On such sites trees would continue to receive zero value in monetary benefit-cost calculations.

Contrasted with that view is the concern of the forest industry for maintaining existing forests for intensive management to meet the predicted doubling of demand for timber in the next several decades.

These and similar contrasting views and concerns emphasize two cardinal points:

1. Under the existing competitive demand-supply market system there is no assurance that present land uses or potential land capabilities will be recognized. This competitive system assures continuing landscape changes associated with shifting land and water uses.

   Calculating benefits on potential uses and ignoring current uses biases decisions. It is wrong. That procedure does not support the science of economics' purpose of promoting the general welfare, but it may improve the economic well being of a few individuals, but frequently at the cost of common property resources.

   There is growing dissatisfaction with the unconstrained market system in allocating uses of resources, whether they be croplands, forests, floodplains or wetlands. Such concerns have stimulated citizens to seek measures to prevent this unconstrained market system from degrading and destroying resources and values important to society.

2. A conservation system is essential to guide, not stop, land use conversions. It should provide the basis for decisions and actions to avoid adverse impacts on natural functioning systems and associated aquatic and terrestrial habitats. Perpetuating the life support values of aquatic and terrestrial ecosystems benefits citizens and the economy, even if most economic procedures and others do not now recognize it. One example illustrates the point.

   Fifty percent losses of all wetlands in the Upper Midcontinent Prairie Pothole Region and the lower Mississippi Delta emphasize the magnitude of natural system service functions and public trust values sacrificed. Among them are natural floodwater storage, flood damage prevention, water quality improvement, and nutrient cycling, as well as fish and wildlife values.

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Simultaneously, taxpayers continue to be asked to pay hundreds of millions of dollars each year for waste-water treatment and man-designed flood control works. The continuing and expanding taxpayer dollar drain to compensate for the loss of original public resource values and to meet runaway disaster relief payments are causing growing citizen, as well as Presidential, concern. The General Accounting Office recently recommended to Congress that natural systems be used to a much greater extent in the Nation's flood control and water quality management programs. That recommendation now awaits implementation, particularly under nonstructural alternatives.

Ineffectiveness of many institutional arrangements to maintain land and water uses and assure ecologically sensitive developments has led to frustrations, debates and court challenges. It is in response to this unsettled situation that growing numbers of professionals and citizens seek improved, consistent ecologically-based guidelines for water and associated land developments, including mitigation and compensation.

ECOLOGICAL FOUNDATION FOR MANAGEMENT

The abundant case histories presented at this workshop for various units of the landscape force closer examination of the natural systems that provide us with products and services at no monetary cost. Characteristics of those systems provide the factual foundation on which mitigation and compensation are sought for degrading impacts on and outright losses of habitats.

Each ecosystem is characterized by energy flow, nutrient cycling, a limited response of self-adjustment to inflicted change, and the capacity for self-perpetuation, given the sun as a source of energy. Each has the capacity to restore itself from stress or damage, unless the system itself breaks down.

In considering mitigation (preventing and minimizing) and compensation (replacing) it is essential to recognize the degree of stress that natural systems undergo. Lightly-stressed aquatic or terrestrial systems adjust to change, and recovery takes place through natural processes when the stress is removed. In contrast, a heavily or overstressed natural system cannot restore its functioning systems to original conditions through natural processes alone. Man has interfered with the system's capacity for maintenance and repair. At this point, man must provide assistance for the system to be restored. These differences in recovery potentials of aquatic and terrestrial systems dictate different management approaches.

The primary management approach is one of preventive conservation designed to avoid an ever shrinking base of certain habitats and costly man-assisted restoration efforts. It is founded on preventing adverse, predictable and irreversible trends or changes in aquatic and terrestrial natural systems. The objective is to maintain as much of existing ecosystems as possible, even if the structure, function and relative importance -- or even the existence of all living organisms organized in food webs -- are not fully known. This can be accomplished through stipulations and conditions associated with permits or certificates required for proposed developments.

Alberta has critical wildlife zones within which key habitats essential to the survival of wildlife populations are maintained -- such as winter ranges, migration corridors and calving or spawning areas. Only land uses compatible with the objective of maintaining these key habitats are permitted on public lands. Provincial fish and wildlife personnel recommend measures to sustain wildlife while accommodating compatible land uses. Discretion at the field level is required to permit tailoring various mineral development activities to sites and times to maintain individual or groups of wildlife species and various habitats used seasonally.

Patterning various oil and gas exploration, development and extraction activities by area and time allows use of those energy resources without irreversible adverse impacts on wildlife. Private companies ensure compliance with regulations favoring wildlife by making it a condition of employment. Companies also have employed biological staff to monitor the effectiveness of mitigation and management measures. Feedback of management experiences improves insight and understanding used to refine existing measures and develop new ones that are needed. Experiences to date in Alberta show that wildlife habitat needs can be incorporated into oil and gas activities. They are confirmed by findings from Florida where threatened and endangered species coexist on electric company lands and waters held primarily for power production or to buffer power plants from residential and agricultural areas.

This overall approach, using stipulations and conditions in permits or leases, is being used widely in oil, gas, coal, dredge, fill, bridge, highway, marina, dam and other developments to avoid unnecessary degradation and loss of natural systems and key habitats in designated areas. Best possible engineering designs are required under the Federal Water Pollution Act to benefit fish and other aquatic organisms.

The heart of the permit or certificate strategy and procedure is the consistency test.

Developments consistent with the objectives for the designated areas can proceed according to the stipulations or conditions. In the United States, for example, a certification procedure is used in conjunction with marine sanctuaries to help advance the conservation, restoration and management goals of the Fisheries Conservation and Management Act of 1976.

Several speakers urged that a program of zero losses be adopted to avoid case by case and cumulative habitat losses. The Bureau of Land Management is attempting to accomplish this on delineated areas of critical environmental concern. They contain important and critical fish and wildlife resources and the natural systems and processes that support them. Developments and activities compatible with the purposes of the delineated critical areas are allowed. California law calls for maintenance of pre-development fish and wildlife resources in the construction and operation of the State Water Project.

This fundamental approach provides a framework for fitting human activities into natural systems. True, they may be stressed temporarily, but recovery can take place through no-cost natural processes. What is required is a stronger base of scientific information for individual situations to improve the quality of management alternatives and decisions. Additional findings from management experiences and research are needed to strengthen field applications.

This need is emphasized by the record of weak inputs to planning many proposed water and associated land developments, as well as to the small number of post-construction evaluations completed. The quality of impact assessements on hydrologic characteristics and man's uses of resources within designated basins and project areas must be strengthened. This rational-scientific approach should be problem oriented, be based on cause-effect relationships, and identify potential preventive as well as other management alternatives. All viable alternatives should be presented, including maintenance of minimum water levels to assure self-purification, low stream-flow augmentation, and other essential functions of natural systems. Such alternatives are fundamental to avoid the type of additional frustrating cases reported for salmon on the Columbia River and the whooping crane on the Platte River in Nebraska.

The second management approach, in addition to preventive measures, is to restore abused aquatic or terrestrial systems or create new ones through appropriate management measures. The critical element is to delineate an area with the potential capacity to develop the desired ecological characteristics in time following application of appropriate management. Estimating the annual primary productivity and potential organism species composition that will develop in the restored or new area is an art gaining in reliability. Restored wetlands of a variety of types, as well as regenerating forests, demonstrate accomplishments, even if the structure and function of the systems remain to be elaborated better. These successes demonstrate that in-kind mitigation and compensation are feasible.

Features to be regenerated should be functional relationships among community members, such as the total annual plant production in a delineated area, rather than the specific mix of plant species. Primary attention should be on net primary production. It is the photosynthetic production of organic substances by plants in excess of their maintenance needs. It is the net primary production by plants that fixes the amount of energy flowing through the rest of the biotic community and is required to maintain ecosystem functioning. Conserving or increasing this base value is important for maintaining the characteristics, including the carrying capacity, of any terrestrial or aquatic system. Oregon requires use of net primary production or biological potential as the basis for replacing estuarine habitats impacted adversely by development. Free choice of methods to restore performance of a natural system should be permitted. Prescriptions must be tailored to specific site conditions, such as when relocating streams or planning disposal of dredged material to develop upland and aquatic habitats.

Only in the 1970s have efforts been underway to place nonmonetary environmental quality values beyond dollar expression on an equal basis with strictly monetary values. The new two-objective Principles and Standards for evaluating water and associated land developments were released in 1973. Preparation of a manual of procedures to implement that two-objective evaluation system is underway. The recognition of functional and habitat values of aquatic and terrestrial systems is weak and needs strengthening. As the banquet speaker stated last evening, the complete manual should be available by the end of 1980.

Thus, the first steps have been taken and more are underway to recognize aquatic and terrestrial ecosystems as capital resources having a flow of products and services important to society. The pressing need has been for a method to identify the productivity values of habitats. Several techniques have been or are being developed. The Habitat Evaluation Procedure, commonly known as HEP, has the potential to improve evaluations of proposed developments.

Experiences to date in planning projects show the values of HEP and nonstructural alternatives. The poster display on the Atchafalaya Basin is a striking example of the importance and usefulness of hydrologic management units and nonstructural approaches to develop a design and management alternative that seeks to perpetuate the functions and productivity of aquatic systems in a unique basin. Other development and planning agencies should duplicate such imaginative designs.

The first paramount step is to replace the inadequate and misleading man-day expressions of value with habitat units and values. Recreational man-day use dollar values, used so freely in the past, have no conceptual basis in economic theory. They fail to measure the existence value of public trust doctrine resources and the continuing stream of products and services from them. Concentrated efforts should be made immediately to finalize a habitat productivity based evaluation system and have it incorporated as standard operating procedure for use in all water and associated land developments. While it must be based on scientific facts, application of the system is an art requiring training of field personnel to use it as a real estate appraiser assesses property values.

It is these types of realignments of institutional arrangements in conducting resource affairs that spawns hope and promise for improved policies to plan, design, fund, construct, operate and evaluate post-construction accomplishments of water and associated land developments. But as many speakers stressed, it is hope resting on the outcome of a variety of pending changes. Six of the more important realignments include:

Realignment 1. Regulations establishing uniform procedures for implementing the procedural provisions of the National Environmental Policy Act will take effect 30 July, 1979. Internal procedures of each federal agency must be aligned to be consistent with this national directive. That may be a difficult task for decentralized organizations, such as the Corps of Engineers. Policies, plans and programs are to protect and balance environmental quality. From the earliest point possible, and continuing through implementation, environmental aspects of proposed actions are to be built into the decision-making process to avoid and minimize adverse environmental effects. This is preventive conservation of the first order and should help improve decisions on proposed water and associated land developments. Actions by each agency are to encourage productive harmony of man and the environment.

Among purpose, policy and mandate sections are additional statements that lay a sound foundation for handling mitigation.

a. Procedures of each agency must insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken. The information must be of high quality, scientifically accurate, and concentrate on the issues that are truly significant to the action in question. The objective is to produce better decisions, with full understanding of environmental consequences. Decisions are to be selected that protect, restore and enhance the environment.

b. Action agencies are to use environmental analyses and proposals of cooperating agencies with jurisdiction by law or special expertise to the maximum extent possible. An interdisciplinary approach shall be used to ensure the integrated use of natural and social sciences.

c. The weighing of merits and drawbacks of various alternatives need not be displayed in a dollar cost-benefit analysis and should not be presented when there are important qualitative considerations.

d. To the fullest extent possible, agencies shall prepare draft environmental impact statements concurrently with environmental impact analyses and related surveys and studies required by the Fish and Wildlife Coordination Act and other environmental review laws and executive orders. A primary task will be to establish more effective coordinated teamwork among agencies. That exists in too few instances now.

e. Mitigation is defined to include:

   (1) Avoiding the adverse impact altogether by not taking a certain action or parts of an action (preventive).

   (2) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

   (3) Rectifying the impact by repairing, rehabilitating or restoring the the affected environment.

   (4) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

(5) Compensating for the impact by replacing or providing substitute resources or environments.

f. Mitigation and other conditions established in the environmental impact statement or during its review and committed as part of the decision shall be implemented by the lead agency or other appropriate consenting agency.

g. Cases requiring an environmental impact statement shall prepare a concise public record of decision. It shall identify whether all practicable means have been adopted to avoid or minimize environmental harm from the alternative selected, and if not, why they were not. A monitoring and enforcement program shall be adopted and summarized where applicable for any mitigation.

Realignment 2. President Carter's 1978 Water Policy Directive that includes a call for mitigation funding and implementation to be concurrent with other project features. When implemented fully, this procedure should avoid delays, exceeding one-third of a century in some cases, involving mitigation and compensation accomplished on projects otherwise completed earlier.

Realignment 3. Fish and Wildlife Coordination Act Regulations were issued in the Federal Register on May 18th, with the initial period for comments closing on July 17, but extended to August 17 as we are at this workshop. Hopefully, these regulations, the first issued since 1934, will be released in final form immediately.

Realignment 4. Federal Water Pollution Control Act consolidated regulations to achieve water quality management goals are in the Federal Register now. They have the potential to help prevent many adverse impacts of chemical, thermal, and mechanical factors on living organisms. Absence of fish, due to acid rain from chemicals released in energy production, emphasizes the pressing need for new technology to curb the fallout. In northeastern North America, an estimated 50,000 to 100,000 lakes more than 5 acres in size are degraded. In Sweden, approximately one-half of its lakes are now fishless. With growing population and expanding demands for energy, it is essential that new technology and procedures be brought on line as soon as possible to permit the degraded lakes to recover and to prevent further degradation.

Realignment 5. Surface Mining Control and Reclamation Act guidelines for mining tract selection and reclamation have been issued recently. They cover non-federal as well as federal lands and activities. A bowl of mineral-tax funds is available to help assure reclamation of mined lands.

Realignment 6. Legal requirements, as well as progressive business procedures, now demand greater opportunities for citizens to participate in the decision making process. A number of speakers at this workshop emphasized the need and values of involving local people in evaluating proposed water and land developments.

As several speakers stated, resource developments will continue. But preventive and corrective procedures and measures must be designed to guide the inevitable landscape changes required for people to maintain a reasonable standard of living. However, demands for energy, food, housing and other essentials of life should not be allowed to be used as crises to justify or lead to resource abuse and destruction. It will require the direct participation of each of us in the political process to ensure that does not take place.

Citizen participation and institutional realignments are essential to forge better working relationships among all concerned. Simplistic and biased participation or non-participation must be overcome. Decisions that are equally sound ecologically and engineering-wise must replace those less adequate. Individuals, especially those who can contribute factual information, must take part in the political process at national, state and local levels to assure sound management alternatives and decisions through more effective teamwork. There is no other way to work effectively with the broad spectrum of values that decision makers are forced to consider to stay in elective office in our pluralistic society.

As several speakers emphasized, better ways must be established to work cooperatively on a stronger rational-scientific factual basis rathe than a weak-casual or confrontation-legalistic basis. Both federal and state agencies expressed this view strongly and repeatedly. We are at a time when new constructive working procedures an relationships must be forged for the good of the resource base as well as for the human resources it supports.

RECOMMENDATIONS

The recommendations are largely as submitted by the Session Chairpersons, lightly edited to eliminate duplication and to arrange them in logical categories. Some duplication still remains, to be sure the complete sense of the recommendations is retained. The explanatory information accompanying some of the recommendations serves as additions to the summary of the workshop. Many of the recommendations could fall in two or more of the categories, but we have included them only once.

General

1. As of 1979 the overall trend of the natural environment and the renewable resources of the North American continent is still toward further degradation and debasement. Soil, water, forests, wildlife, fish, scenic attributes, air--all are currently suffering further diminution, on balance. This centuries-long slide should be stopped in the 1980s and a rehabilitative recovery sequence should then commence. Numerous policy tools other than mitigation should and will be used to halt this slide and reverse the trend.

2. The term mitigation refers to a class of actions which have the purpose of counteracting the effects of disruptions, on the natural environment and on renewable resources, associated with new physical structures and/or construction activities and/or new management objectives and practices. The connotations of mitigation should not be extended to encompass those more properly reserved for such terms as regulation, preservation, conservation, restoration, reclamation, enhancement (melioration), rehabilitation, compensation, substitution, palliation, etc. The usual tendency of a policy slogan to attract too many connotations should be contained.

3. Development projects should be designed when possible to avoid degrading existing natural systems. This preventive approach is favored over substituting one habitat type or ecosystem type for another. On-site mitigation should be required in most coastal situations.

As applied in practice heretofore, mitigation has seldom amounted to more than post facto token acknowledgement of some "unfortunate disruption". Where it has been addressed ante facto, mitigation may have been little more than the sugar coating to render a bitter pill more palatable. Development-oriented agencies and industries are now committed to do justice to all the necessary and sufficient provisions for mitigation at all stages of a project. They should be held to this commitment.

4. In the new symbiotic era now dawning, the experts on the environment and renewable resources should and will provide relevant information, insights and advice on schedule. Preliminary work will include interdisciplinary synthesis. Many scientists and managers already are competent to do these things. The proceedings of dozens of relevant symposia, reports of hundreds of studies, and data banks containing millions of numbers are fully available. The challenges to collaborate on a coequal status with engineers, lawyers, economists and public administrators are to be welcomed by the environmental and resource scientists. The roles of the latter can only gain in importance through the rest of this century.

5. Each agency should now prepare and publish an agenda for the future which would contain a five or ten year, step by step, agency plan and timetable to improve its practices with respect to fish, wildlife and other features of the natural environment.

6. A guidance document of mitigation techniques should be prepared as a joint effort of relevant federal agencies. Some techniques, such as coastal marsh and island creation are well developed, and should be catalogued for daily field use.

7. Provide the capability to respond quickly to requests by federal action agencies for a range of habitat management alternatives and their costs.

8. The Nation's fish and wildlife resources, in terms of quantity and quality, should be protected from any further diminishment as a result of federally financed, constructed, operated or permitted projects.

9. Final uniform rules and regulations for compliance with the U.S. Fish and Wildlife Coordination Act should be promulgated as soon as possible with the clear intent of meeting recommendations. There is danger that prolonged delay in their adoption will serve to unduly weaken the regulations as well as dissipate the existing sympathy in Congress for strengthening the Coordination Act.

10. There is a need to provide a mechanism requiring review and retrofit of existing federal projects in order to rectify longstanding adverse impacts to fish and wildlife

resources. Included should be authority vested to the fish and wildlife agency of the affected resources to initiate and complete the review, with costs to be reimbursed by the federal project.

Examination of a number of completed or partially completed projects reveal varying degrees of unfulfilled fish and wildlife mitigation measures. Some measures have not been implemented. Others have been partially implemented or are ineffective in their original purpose. It is likely that many projects can be retrofitted with feasible features that would result in the recovery of substantial amounts of project-caused fish and wildlife losses.

The outstanding example of this problem was where substantial unmet mitigation needs related to Corps projects in the Lower Mississippi River were described. Other papers described similar circumstances elsewhere. It is essential that the strongest possible message be sent to the President and Congress concerning the grave problems in the Lower Mississippi as well as the other areas documented by papers presented at the Symposium.

11. Uniform and clear definitions of terms describing the relationship of projects and fish and wildlife resources including ones for mitigation, enhancement, compensation, conservation, preservation, project, wildlife agency, wildlife and wildlife resources should be developed and incorporated into the rules and procedures governing application of the Act.

In order to achieve equal consideration and fair treatment for fish and wildlife it is essential for all agencies and professionals to use and implement commonly understood terms. We agree that NEPA's definition in Section 1508.20 should be the universal definition for "Mitigation".

12. It is essential that wildlife agencies responsible for the protection of fish and wildlife in an area to be affected by a project be fully consulted in a timely manner prior to authorization of projects with a view toward identifying impacts to fish and wildlife measures necessary to prevent or offset project-caused losses. It is especially critical that the views of the wildlife agency with the custodial responsibility for the affected resources be the agency funded and assigned to provide the preauthorization evaluation.

13. Federal project land acquisitions for fish and wildlife purposes should be treated in the same manner as necessary land acquisitions for other project purposes.

There is often a prevailing attitude among project beneficiaries that land acquisitions for project purposes should be limited to that required for physical features such as the reservoir site. A strong message needs to be delivered that land acquisition necessary to aid in offsetting project-caused losses to fish and wildlife are no less essential to the projec than other project-purpose acquisitions.

Condemnation should be used as a measure of last resort after all attempts to acquire suitable mitigation lands by easement and on a willing-seller basis have been exhausted. Where that is impossible, the project should be reevaluated and either modified to avoid the need for mitigation, or, failing that, abandoned.

14. Biological judgments should be included in final mitigation requirement statements; e.g. trade-offs of summer range may reduce fawning, but if for a gain of winter range, winter survival may increase. A biological decision is required to determine what the final result will be.

15. Seven basic steps for mitigation where biological input is needed were proposed:

a. Solid wildlife data base for both project and proposed mitigation sites.

b. A thorough and complete data analysis.

c. Predictive models developed to create conceptual mitigation options.

d. Design of required habitat modifications for mitigation.

e. Designs must be implemented.

f. The mitigation success should be monitored.

g. Modifications to ongoing mitigation activities resulting from the monitoring program, should be agreed to and be budgeted for by development agencies at the planning stages.

16. Expert consultants should be used during various phases of the mitigation design. It has been proven to be cost effective to pull in such specialists rather than to proceed with only general input to the mitigation plan.

17. Public lands may provide opportunities for mitigating losses in habitat amount and diversity through special enhancement activitie and multiple use planning. A site may become a "Area of Critical Environmental Concern", or ma be modified to enhance the continued existence of a species in a region where habitats off public lands are rapidly being lost.

18. To avoid damage to wildlife resources, and thus the need for mitigation, implement the following: (a) better and earlier project planning, (b) stringent criteria (e.g., those in Carter's Water Policy Message of June 1978) for project approval, and (c) heavier emphasis on non-structural alternatives (e.g., providing transfer money to wildlife agencies to study non-structural solutions).

19. Amend the draft FWCA regulations to acknowledge that ordinarily bare acquisition without management will not fully compensate habitat loss, but might in some cases.

20. A relatively small representative work group, including state wildlife agency representatives, should be selected to deal with issues raised at this Mitigation workshop. It is critical to have this mechanism to face the speed-up of energy development and related impacts on fish and wildlife.

Energy Developments

21. The current energy crisis may help to stimulate more efficient and effective collaborative decision processes with respect to mitigation and other classes of environmental action. It need not and should not lead to excessively quick judgments on the basis of very partial information, or an overall relaxation of policy standards with respect to the natural environment and renewable resources. Before any rare species of fish be extinguished in the interest of some new gasoline refinery, such obsolete technological species as Automobilus gas-guzzlers should be sacrificed. There is still much scope for reducing the demand for energy. It has been remarked that objective truth is the first casualty of a war. Similarly, our fledgling ecological rationality is threatened and may become the first casualty of the energy crises.

22. Do not be stampeded by the current emphasis on coal for synthetic fuel. The habitat impacts will go beyond site impacts to traditional development versus habitat preservation issues. Traditional conflicts relate to development impacts on water, wetlands and riparian zones. They will continue to be important, as will regional land use trends.

23. The Office of Surface Mining should modify its rigid restrictions on intermittent and permanent ponds, and high walls which may be valuable for wildlife.

24. To meet a legitimate need for power, a utility should approach the environmental licensing bar with a demonstration that, within the range of siting options and station configurations available to it, it has the best plan for managing the mitigation and, if possible, providing enhancement of fish, wildlife, and other environmental values.

Estuaries and Coastal Zone

25. Estuarine ecosystem land and water use planning, including identification of potential mitigation sites, should be required by the Office of Coastal Zone Management of each coastal state with an approved coastal zone management program. This may be the only way to consider and avoid long term accumulative impacts of individual projects.

26. Mitigation should be used to maintain the surface area, tidal prism, and water quality of an estuarine ecosystem. Fish and Wildlife resources depend on these parameters. An understanding of the physical and biological components of the estuarine ecosystem are necessary to mitigate for a proposed project. The mitigation concept should be shifted to identify significant features and roles of a development site in the overall estuarine ecosystem and subsequently identifying a mitigation site to replace those original roles if lost or degraded through development.

27. The Office of Coastal Zone Management should require states to develop mitigation requirements to maintain our nation's estuarine ecosystems. The public trust doctrine should be included in each state's coastal zone management plan.

28. The State of Oregon should develop detailed implementing procedures for its mitigation requirement to be used as a model for national/state coastal zone management.

29. The simplistic view of maximizing one kind of habitat at the expense of others should be avoided, e.g., deposition of dredge materials in benthic invertebrate production areas for salt marsh creation.

30. A local-state-federal team to review Section 10 and 404 permit applications and ensure successful mitigation, should be organized by each state coastal zone management authority.

31. Documentation of the importance of intertidal macrophyte algae to the estuarine ecosystem should proceed immediately.

32. Current practice provides oil spill contingency funds for cleanup operations, but there is no allocation or withheld reserve from such funds for post-cleanup mitigation actions. Oil spill liability should include assessment of long term loss and a requirement for mitigation to offset long term losses.

Research Needs

33. Mitigation-oriented research should proceed, potentially funded under coastal zone management and similar authorities.

34. A crash program should be developed to identify acceptable procedures to establish non-market as well as economic values for fish and wildlife. This is needed to augment biologic data.

Public Information

35. Federal construction agencies must be pubicly accountable through public hearing and review for rejection of recommendations by wildlife agencies related to preventing or offsetting project-caused impacts to fish and wildlife resources.

Too often in the past, proposed measures for protecting fish and wildlife from project impacts have been rejected out-of-hand by construction agencies. Often this has been done in order to achieve favorable cost/benefit ratios or to relieve certain project beneficiaries from funding the mitigation costs. It is essential that this process be exposed to full public review and the burden of establishing "why it is not in the public interest" to accept wildlife agency recommendations for projects be placed squarely on the shoulders of the federal construction agencies.

36. More attention is needed to provide an adequate public information field staff in such programs as wetland preservation that involve extensive private landowner contact.

37. That the "Guidelines to Minimize Impacts", currently being revised by the Environmental Protection Agency, be released and publicized as quickly as possible. Presently, there is no stated protocol or procedures for mitigation as related to the private sector. A firm statement of acceptable procedures is needed in order to eliminate or maximize the need to "negotiate" mitigation.

38. The Secretary of the Interior and the Army Corps of Engineers should be required to submit periodic reports to Congress at least on an annual basis concerning the timely implementation and effectiveness of fish and wildlife compensation measures for federal projects. Such reports shall be based on findings of the federal construction agency, including consultations with the affected wildlife agencies.

This recommendation is consistent with the President's policy directives.

39. There is a need to require federal permit-issuing agencies to consider seriously and respond to the requests of wildlife agencies on permit violations and failure to require permits for non-federal projects. The response to such requests should be subject to a public hearing if the affected wildlife agency so requests.

40. There is a very essential need to reconvene the National Coordinating Committee (NCC) on a regular annual basis in accordance with the Action Report. The U.S. Fish and Wildlife Service should be requested to reconvene the NCC in late 1979 or early 1980 in Washington, D.C. for purposes of reviewing progress on implementation of the Action Report and reviewing the recommendations of the Mitigation Symposium.

A brief review of the report reveals that virtually all of the problems revealed during this Symposium are indeed covered by the report' 169 recommendations. The only difference between now (1979) and then (1971) is that better case history data are available at this time.

41. A federal extension program should be developed to provide to fish and wildlife the same level of services now provided to agriculture. Emphasis should be given to method of replacing lost or impacted fish and wildlife, including losses sustained during the habitat development interim.

Riparian

42. Where agencies lease public land for grazing, there should be, as a condition of the lease, provision for protection of riparian vegetation from excessive grazing.

43. There is need for development of a three-pronged strategy for mitigation on lakeshore wetlands: restoration, enhancement and substitution. We observe that the recent General Accounting Office report on wetlands states that the food and fiber needs of the nation can be met without further drainage of wetlands.

Funding

44. More wildlife resources and post-project assessments of effects on fish and wildlif are needed. Costs of pre-project and post-project assessments should be budgeted as part of the basic project costs.

45. On the matter of project costs, it is essential that all costs for fish and wildlife mitigation and compensation measures including operation, maintenance, replacement and all necessary studies are always included as costs in the project's cost/benefit ratio.

It is time that the full costs of projects, including the identification of project-caused wildlife problems and the corrective measures necessary to restore these publicly-owned resources, be reflected in the cost/benefit ratio. It is not enough for the project to provide land acquisition and capital improvement features for offsetting project-caused wildlife losses. It is also necessary for the project to provide operational, maintenance and replacement costs for such wildlife features. After all, if it were not for the project, such features would not be necessary.

46. Costs for mitigating and compensating project-caused fish and wildlife losses must be charged to and reimbursed by project beneficiaries whenever vendable products or benefits are produced for specific beneficiaries.

It is absolutely essential to maintain the principle that costs for measures necessary to offset or compensate for impacts to publicly-owned resources such as fish and wildlife must be paid for by those who benefit from the project causing the impacts. It is wrong to simply relegate such costs to the general taxpayer if such vendable products and special beneficiaries can be identified. To not require reimbursement and shift such costs to public funds would in fact be charging the public for protecting resources which they already own. In other words, the public would be subsidizing the project-benefits to special interest groups with the Nation's wildlife heritage. Moreover, relegation of such costs to non-reimbursable status would make it more convenient to delete them in the budget process with the result that more marginal projects would receive favorable cost/benefit ratios.

In the case where the project benefits the public as a whole and no vendable products are produced or no specific beneficiaries can be identified, then costs for fish and wildlife mitigation and compensation features should be entirely a non-reimbursable federal cost.

47. Enhancement features for fish and wildlife should be designated as a non-reimbursable cost and not charged to project beneficiaries.

In cases where project features are incorporated that improve fish and wildlife above pre-project levels, it is appropriate that the costs for the features not be charged to project beneficiaries. However, enhancement credit should not be granted until all mitigation and compensation features have been implemented or at least committed to in the project's budget.

48. Federal construction agencies must be required to provide in their budgets sufficient funds to carry out needed pre- and post-authorization fish and wildlife studies and evaluations. Such funds must be an integrated feature of the project budget and not subject to selective deletions.

Because proposals for federal projects necessitate the examination of a variety of project features, it is appropriate that funds to examine the project's impacts on fish and wildlife be provided in the federal construction agency's budget. Moreover, such budgeting reflects the true cost of the project with relation to fish and wildlife.

49. Funds budgeted by federal construction agencies for fish and wildlife studies and evaluations related to proposed project should be made available first to the state wildlife agency of the affected state on a direct transfer-through basis.

It is the state wildlife agency which has the custodial responsibility for protecting fish and wildlife resources that may be affected by a proposed project. Therefore, it is appropriate that federal project funds for studies be made available first to them in the most direct and timely manner possible.

50. Funding for and implementation of fish and wildlife mitigation and compensation features including acquisition of wildlife lands must occur concurrently with such measures for other project features.

The need for this recommendation has been amply documented by papers on case histories of specific federal projects. It is consistent with the President's policy directives.

51. Amend the Federal Water Projects Recreation Act (P.L. 89-72) to delete the requirement for local cost-sharing of enhancement measures, while retaining the requirement that such measures be economically justified.

Operation and Maintenance

52. Mitigation funding needs to be provided for operation and maintenance of vegetative habitat downstream from impoundments. Crane habitat is a prime example.

53. Assure that any federally funded water development conservation program include the necessary system of monitoring fish and other aquatic life to account for the most efficient operation of river systems addressing multiple water uses. Such efforts are needed to facilitate the enforcement of statutes relating to the efficient use of consumptive water rights and the maintenance of agreed upon instream flow requirements.

54. It is essential to routinely require post-project monitoring, evaluation and correction of oversights or deficiencies of fish and wildlife mitigation and compensation measures for federal projects.

Most of the papers in the sessions on mitigation presented real evidence that such measures are needed if federal projects are to be expected to fulfill their mitigation and compensation obligations.

Habitat Evaluation

55. Application of the Coordination Act must be based upon a habitat evaluation procedure to identify project-caused impacts to wildlife habitat values. Assignments of dollar values to hunting or angling, i.e. user days, are not to be used as a basis for identifying mitigation, compensation or conservation requirements of the project.

56. Recognize that "front ending" of fish and wildlife resource considerations, in place of the "backending" that has been called mitigation, requires quantitative habitat measures. Support and participate in efforts to secure habitat measurements.

57. Support development of the environmental quality account under the national Principles and Standards used to plan and evaluate proposed water and associated land developments. Support attempts to relate habitat measurements to management.

58. The U.S. Fish and Wildlife Service's Project Impact Evaluation Group should examine the habitat evaluation methods presented in these sessions, as well as other evaluative methods, and should publish a paper discussing the advantages and disadvantages of these various techniques. Are there alternatives to the Service's Habitat Evaluation Procedures (HEP), or do they contain components that could be incorporated into HEP?

59. A requirement in predisturbance studies should include the determination of local habits of species prior to designing mitigation measures.

60. Mitigation objectives should be required to be stated in measurable terms, such as acres of specific habitat components capable of supporting a given minimum population size.

61. Biomass should be measured for each important kind of organism in environmental impact studies (or management evaluations) rather than just using species lists or estimates of numerical abundance. This was illustrated in the paper, "Estimated Benefits to Stream Benthos from Low Flow Augmentation Below a Hydro-Electric Facility." In most natural populations, some older, larger animals each far outweigh others that are younger but far more numerous. In aquatic populations, the weight difference between largest and smallest members is often several thousand fold. Loss of only the few larger (and probably much more valuable) members, as often happens, owing to environmental damage such as diminished cover or water depth, may hardly be noticed if the measure of abundance is strictly numerical but will be strikingly evident if change in biomass is watched. Better yet, the complete size and age structures of each population and the natural (background) variability of these should be known in addition. There are other population data that it would be ideal to measure, as well, but if rough measures of abundance are appropriate, biomass should be considered a minimum.

62. Understand that the cost of mitigation alternatives must include financial outlays plus foregone economic benefits.

63. Be willing to make judgments as to relative ecological benefits of mitigation alternatives.

Legislative/Political/Institutional

64. Explore innovative institutional approaches. These can include (a) single resource transferrable development rights, (b) incentive systems for mitigation on private lands, (c) management for complementary resource objectives on public mitigation lands, and (d) others.

65. Before federal funds be provided for further development or rehabilitation of irrigation facilities, require that the states make appropriate legislative and administrative provisions to insure protection of water quantity and quality and wetlands and instream flow values.

66. Assure that fish and wildlife interests are included in a major role in any interdisciplinary analyses which may be proposed as part of a cooperative water conservation program aimed toward developing a total water use plan within each state.

Such multi-interests analysis leading to total water use plans must include assessment of off-site benefits such as enhancement of stream flows, water quality and ground water.

67. As part of any proposed new water use and conservation program, the federal government should aid the states in developing comprehensive and easily accessible records of water use, emphasizing water quality and

quantity, irrigation efficiencies and instream flow needs for specific stream reaches within the appropriate hydrologic unit.

Through such efforts, the federal government could encourage the enforcement of water use efficiency statutes in the various states. This is necessary to establish the forfeiture and abandonment of water rights. Such forfeited or abandoned rights could then be assigned to other beneficial uses, including fish and wild life.

68. It became clear from the papers and discussions during these sessions that the amendments to the Fish and Wildlife Coordination Act and the revised Principles and Standards must resolve the definitional problems surrounding these terms: loss prevention, mitigation, compensation, enhancement, etc. Therefore, we urge all interested agencies and individuals to review these draft documents and express their views during the appropriate response periods.

69. Create incentives (e.g., tax measures, certificates of merit, zoning) to encourage private landowners to maintain wildlife habitat, especially wetlands, on their lands. Increase public information and education programs to educate the public to the economic value and important natural functions of wetlands.

70. Amend the draft FWCA regulations to require in the case of federally-permitted activities, simultaneous, rather than pre-application, consultation, meaning that wildlife consultation should take place at least as early as other required review (e.g., air/water quality).

71. Fish and Wildlife Coordination Act or addition legislation must include activities of all federal actions which impact terrestrial as well as water development projects. States should enact similar legislation for their projects. California and Colorado have legislation useful to other states.

72. The federal government and states should prepare environmental quality plans through a program similar to the recreation planning required by the Heritage Conservation and Recreation Service. The area-wide plans required under Section 208 of the Clean Water Act may be a helpful step in the right direction.

Water Resource Planning and Management

73. When water conservation measures result in a reduction of incidental water use needed to maintain vegetative wildlife habitat, a portion of the salvaged water should be desigated for development of fish and wildlife habitat.

74. Insure that adequate minimum flows are provided for in every federal water project; that minimum release agreements are executed and incorporated into reservoir operating plans; that commitments to enforce such minimum flows are expressly set forth in environmental impact statements; that monitoring plans using U.S. Geological Survey water flow measurements are implemented; and that operators report any minimum flow violations to the appropriate wildlife agency.

75. Closer examination of the "natural" mitigation effects that accrue from deltas formed in reservoirs is recommended. This should include examination of the effect of different reservoir water levels on the build-up and loss of delta areas.

Management Measures

76. Attempts should be required to move grouse leks from development sites to "safe areas". Winter use areas must be determined prior to selecting a site for the establishment of an artificial display ground. Site preparation requires the removal of all shrubby growth through use of blades or scrapers from an area approximately five acres in size. Lek activity sounds should be broadcast with automatic equipment activated daily one hour before sunrise for a four-hour period each morning beginning in early March. At least two years should be planned to attract some adults during the first year and reinforce the use of the area during the second year.

77. To mitigate for tower and other structure bird kills, siting should be away from known migration routes. Reflective surfaces should be minimized. UV or infrared lights should be substituted in ceilometers. On-off cycles should be used for all warning lights, and unnecessary lighting on the surface or within structures should be extinguished during migration periods.

78. Primary mitigative measures for ungulates such as mule deer should include land acquisition and protection for critical habitat types, management of the time and location of other human disturbances resulting from the new development, and standard vegetative management techniques

79. Increasing vegetative structural elements are required to mitigate for impacts to avian populations. This is important in all seasons of use, not just during the breeding season. Where replanting is a desired mitigative technique, on-site germination and wildstock cuttings should be used rather than nursery stocks.

80. A major mitigation approach in dam building is to design for reservoir water withdrawal at various depths (multiple-level release). Such facilities allow the knowledgeable reservoir operator to adjust downstream habitat to complement and enhance composition of the river biota.

81. Computer simulation can aid greatly in developing mitigation plans for rivers that are slated for flow regulation. The approach of examining by rapid computer simulations the various logical alternatives in river management and mitigation which was described in the last paper of our session was similar to the approaches in various papers elsewhere in the Symposium.

82. The commonalities of approach and even of some detail in terrestrial and aquatic habitat evaluation and mitigation/management decision-making are most striking and encouraging. Therefore, further communication between us should be pursued in future development of procedures.

83. Established water projects should be examined for ways their habitat areas and their facilities can be modified for benefit of fish and wildlife. Examples of alterations that can be made are discussed in the papers, "Combining A Dust Abatement Project With Wildlife Enhancement On Canyon Ferry Reservoir, Montana", and "Potential Use of Hydroelectric Facilities For Manipulating Fertility of Lake Mead". In the first paper, creation of islands dramatically increased wildlife numbers, especially waterfowl. The second paper describes how altering the depth or season of discharge could manipulate fertility of a reservoir for fisheries benefits.

Keynote:

Federal Legal Background for Mitigation[1]

Leo M. Krulitz 2/

This paper examines the statutory basis for mitigation of fish and wildlife losses caused by federal or federally-approved water projects, discusses the most significant judicial interpretations of those authorities and what impact they have had in practical terms. Also examined are the major unresolved questions about mitigation and likely areas for future discussion.

INTRODUCTION

The Fish and Wildlife Coordination Act--the basis for mitigation as we mean it here today--was conceived by Congress in 1934. Despite changes in 1946 and 1958, the Act remained lodged in an inhospitable twilight of sorts. In retrospect, the 1934 Act was an idea that was premature. The conditions in the country necessary to fulfill the promises of the Act did not come into place until several decades later.

The Act and the concept of mitigation could only mature as the society in which it operated matured. As has been the case with most of the important social initiatives of the past decade and a half, the prophet, the shaper, the shepherd of that maturity has been the federal courts.

In 1967, more than 30 years after passage of the Act, the Supreme Court enunciated the enduring public interest philosophy so important to mitigation as it now exists.

The court was faced with a federal agency which argued that it had no obligation to require mitigation as part of a project--or to deny approval for a project--which had the obvious potential for serious adverse impacts on fish and wildlife resources. The court said: 3/

> The objective of protecting "recreational purposes" (stated in the Federal Power Act) means more than that the reservoir created by the dam will be the best one possible or practical from a recreational viewpoint. * * * Mr. Justice Holmes once wrote that "A river is more than an amenity, it is a treasure." New Jersey v. New York, 283 U.S. 336, 342. * * * The grant of authority to the (Federal Power) Commission to alienate federal water resources does not, of course, turn simply on whether the project will be beneficial to the licensee. Nor is the test solely whether the region will be able to use the additional power. The test is whether the project will be in the public interest. And that determination can be made only after an exploration of all issues relevant to the "public interest," including future power demand and supply, alternate sources of power, the public interest in preserving reaches of wild rivers and wilderness areas, the preservation of anadromous fish for commercial

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1/ Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 17-19, 1979.

2/ Solicitor, U.S. Department of the Interior, Washington, D.C. This paper was prepared with the assistance of William W. Garner, Division of Conservation and Wildlife, Office of the Solicitor

3/ Udall v. FPC, (High Mountain Sheep Dam), 387 U.S. 428, 437, 450 (1967)

> and recreational purposes, and the protection of wildlife. The need to destroy the river as a waterway, the desirability of its demise, the choices available to satisfy future demands for energy - these are all relevant to a decision under § 7 and § 10 but they were largely untouched by the Commission.

Three years later, in 1970, the Fifth Circuit Court of Appeals, in language as eloquent as any I've read on the subject, further defined not only the right but the obligation of the federal government to be mindful of the impact on fish and wildlife in committing or permitting certain acts. The issue in that case was whether the Secretary of the Army could consider anything except navigational questions in denying a permit to two Florida landowners to fill 11 acres of Florida Gulf tidelands to build a trailer court. The Fish and Wildlife Service protested--and the landowners themselves conceded--the likely damage the fill project would do to the ecology of marine life on the bottom.

The Circuit Court wrote: [4]

> We hold that nothing in the statutory structure compels the Secretary (of the Army) to close his eyes to all that others see or think they see. The establishment was entitled, if not required to consider ecological factors and, being persuaded by them to deny that which might have been granted routinely five, ten or fifteen years ago before man's explosive increase made all, including Congress, aware of civilization's potential destruction from breathing its own polluted air and drinking its own infected water and the immeasurable loss from a silent-spring-like disturbance of nature's economy.

Thus was the traditional notion of mitigation transformed. No longer could it be treated simply as an add-on frill, a social nicety--a "consult and forget" or "consult and ignore" obligation in water project planning. That traditional notion was supplanted in federal law by the idea that the public interest requires an analysis of whether a project may even be authorized in view of its fish and wildlife impacts and the mitigation required.

This idea was also embraced in the National Environmental Policy Act (NEPA). To again quote the Fifth Circuit Court in Zabel, "The parallel of momentum as the three branches shape a national policy gets added impetus from NEPA.

"This Act essentially states that every federal agency shall consider ecological factors when dealing with activities which may have an impact on man's environment." [5]

But even in NEPA, federal law does not provide a definition, much less a consistent direction, on how federal agencies are to deal with the question of mitigation in project planning, approval, and implementation. It has fallen to President Jimmy Carter, after all these years, to issue the directives intended to get federal agencies moving seriously--and in concert--on mitigation programs.

In May 1977, President Carter issued three Executive Orders which have particular relevance to mitigation. In E.O. 11988 (floodplains), the President recognized that unwise development in floodplains destroys wildlife habitat, agricultural and forest products, stable ecosystems, and park and recreation areas. The President directed federal agencies to observe several directives designed to avoid or minimize the impacts of federal actions on floodplains.

E.O. 11980 (wetlands) contains an even more substantive directive to federal agencies not to undertake or provide assistance for new construction located in wetlands unless there is no practicable alternative and all practicable measures have been included to minimize harm to wetlands.

Finally, in E.O. 11991 (NEPA), the President directed the Council on Environmental Quality to promote the development and use of indices and monitoring systems to predict the environmental impact of proposed public and private actions, as well as the effectiveness of protection and enhancement proposals.

In his 1978 Water Policy Message, President Carter stressed his belief in the importance of mitigation in federal activities. He directed federal agencies to:

1. Revise the Principles and Standards

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[4] Zabel v. Tabb, 430 F.2d 199 (5th Cir 1970).

[5] See Zabel v. Tabb n. 4, supra.

(P&S) of the Water Resources Council to require explicit formulation of nonstructural alternatives in federal water and related land resources project plans.

2. Recommend for authorization only those projects which contain funding for mitigation concurrent and proportionate with construction funding. Designate funds for environmental mitigation in water project appropriation requests.

3. Issue annual reports on compliance with environmental review requirements, on project-by-project basis.

4. Plan and operate new and existing projects to protect instream flows, consistent with State law. Amendments to authorizing statutes should be sought where needed.

5. Issue rules under the Fish and Wildlife Coordination Act (FWCA) which, among other things, should "include acceptable methods for determining adequate measures to prevent or to mitigate losses ..." to fish and wildlife.

FEDERAL LEGAL BACKGROUND FOR MITIGATION

I am unaware of any federal statute or case law which defines the term "mitigation."

The simple dictionary definition of the word is not seriously at odds with what we know the Congress intended--and what the courts have supported--in authorizing mitigation measures. The process of mitigation, taken in its non-wildlife context, is, after all, fairly routine. Federal construction agencies have without question or quarrel accepted the responsibility of offsetting project impacts on property interests. Roads and powerlines have been rerouted, ranches, farms, resorts and other businesses bought and paid for, entire communities relocated, all in the normal course of project planning and construction.

What is at issue--and what must really concern us here today--is how--not whether--fish and wildlife losses should be measured and offset. In the Coordination Act, the Congress has been very clear in its view that those resources are to be given "equal consideration" with other values. As you know, those values have not always been equally considered. And, too often when they have been considered we have used the traditonal marketplace, dollars-and-cents measurements which are difficult to relate to fish and wildlife.

If a definition is needed for a starting point, we can paraphrase the NEPA rules: mitigation means avoiding, minimizing, rectifying, reducing or compensating for project impacts on natural resources during project planning and implementation. 40 C.F.R. §1508.20. The proposed FWCA regulations, I think, subsume these aspects in a straightforward definition:

"'Mitigation' means (1) lessening wildlife resource losses to a project through use of loss prevention measures and (2) offsetting losses through use of other structural and non-structural measures."

If any further distinction is necessary, it is only between mitigation and the closely-related idea of "enhancement." The proposed FWCA rules define "enhancement" as measures adopted in planning and project implementation which develop or improve resource values beyond that which would exist without the project.

Mitigation includes the idea of preventing the loss of fish and wildlife values. Consequently, an analysis of the "Federal Legal Background for Mitigation" could potentially include statutory programs which safeguard resources critical to fish and wildlife such as:
(1) the Clean Water Act, including particularly §§ 402, 404, 102(b), and 303 programs; (2) the Coastal Zone Management Act; (3) program authorities of the Federal land managing agencies; (4) the Water Resources Planning Act of 1965 (P&S); (5) Federal Power Act, (6) Estuary Protection Act; (7) the program authorities of the Fish and Wildlife Service, the National Oceanic and Atmospheric Administration and the Environmental Protection Agency; (8) River and Harbor Act of 1899; (9) Endangered Species Act of 1973; (10) general authorities of the Corps of Engineers, the Soil Conservation Service, the Tennessee Valley Authority, and the Bureau of Reclamation; (11) interstate water compacts; (12) FWCA; (13) NEPA.

Additionally, Federal common law doctrines provide some basis for mitigation, in the sense of preventing losses of fish and wildlife; such as: (1) nuisance, including the protectable interest of the United States in pollution-caused damage to migratory birds or endangered species; (2) trespass on federal property interests, including water rights; (3) Indian treaty rights; (4)

equitable apportionment by the Supreme Court of interstate streams or their fisheries resources; (5) navigation servitude.

The general principle reflected in all of these statutes and common law doctrines is that fish and wildlife values must be considered in the federal decision-making process and, in some instances, can determine the outcome of those decisions. Consultation with wildlife agencies is often required so that the action agency can obtain the views of experts on impacts and mitigation requirements.

While I think it is important to recognize the relevance of these legal authorities to mitigation, I do not propose to elaborate on them here. Instead, I want to make some general observations about the laws and legal principles which have operated to require, and in some cases to frustrate, mitigation in the past. In so doing, I will try to underscore fruitful areas of debate for the future.

FEDERAL WATER PROJECT LAW

Outside the requirements of the FWCA, federal legal recognition of mitigation was historically confined to site-specific federal water project statutes. Several legal scholars have traced the growing Congressional consciousness over this Century of fish and wildlife needs associated with Federal water projects, 6/ noting the gradual expansion of the multiple-purpose project approach to include fish and wildlife resource considerations. I would add several observations not made by those scholars.

First, in addition to site-specific mitigation plans, the Congress has authorized several, important basin-wide mitigation proposals. The so-called Mitchell Act 7/ authorized a vast federal program independent of individual Federal water project authorizations to conserve the fishery resources of the Columbia River. By the Act of August 27, 1954, 16 U.S.C. § 695d. The Central Valley Project, California (CVP) was declared to be authorized to construct, operate, and maintain waterfowl production areas and refuges using CVP water sources.

Section 8 of the Colorado River Storage Project Act, 43 U.S.C. § 620g, is another significant example of a basin-wide mitigation authorization. In theory, at least, the Federal Power Act is also such a statute. 16 U.S.C. § 797(e). The Federal Energy Regulatory Commission --successor to the Federal Power Commission-- is exercising its river system planning authority to examine fisheries problems on the Columbia and Connecticut Rivers.
Second, the Congress has actually authorized at least one federal water project (Washoe Project, Nevada) for the purposes of offsetting the adverse impacts of another federal water project (Newlands) upon fish and wildlife resources. 70 Stat. 775, 43 U.S.C. § 614. These measures were considered enhancement because the degraded environmental conditions which resulted from the Newlands Project, were taken as a given, "without-the-project" baseline.

Finally, there are examples of Federal water projects which have been authorized with specific directions to the administering agency to provide stated levels of instream flows: Trinity River Project (California), Section 2 of the Act of August 12, 1955, 69 Stat, 719; New Melones Project (California), Section 203 of the Act of October 23, 1962, 76 Stat, 1191.

However, the lesson learned in the New Melones Dam case (California v. U.S., n. 6 supra) is that the Congress needs to be specific in declaring its intent that a given Reclamation Project should be operated to achieve wildlife resource objectives. If the Congress is not explicit, and a given state water authority does not agree with federal project administrators on the flows necessary to meet those objectives, the state's preferences may prevail.

GENESIS OF MITIGATION COST REPAYMENT PHILOSOPHY

The question of who pays for mitigation has had a strong effect in determining whether there will be mitigation. Congressional treatment of reimbursability has varied over the years. Mitigation costs have historically been treated like other Federal project costs, and are thus reimbursable in part, as computed using the

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6/ Richard L. Dewsnup and Dallin W. Jensen, Identification, Description & Evaluation of Strategies for Reserving Flows for Fish & Wildlife, prepared for the Fish and Wildlife Service, Western Energy and Land Use Team, WELUT Project 23, Phase 1 (February 10, 1977).; 2 E. Clyde, C. Corker, E. Morreale, J. Sax, A. Utton, Water and Water Rights (R. Clark, ed. 1967). Brief of the United States in State of California, et al. v. United States, 438 U.S. 645 (1978).

7/ Act of May 11, 1938, 16 U.S.C. § 755.

standard allocation formula developed by the Federal construction agencies. In 1946, the forerunner statute to the FWCA was amended to provide that mitigation costs were to be considered non-reimbursable on reclamation projects. 60 Stat. 1080. In 1965, the Federal Water Project Recreation Act (FWPRA) removed this proviso for reclamation projects. 8/

The general theory apparently expressed by current law is that beneficiaries ("sponsors") of Federal water projects are responsible for reimbursing the government for their share of the cost of mitigating the impacts of fish and wildlife caused by the project. To the extent that project costs are attributable to non-reimbursable purposes--such as flood control--a proportionate share of the total mitigation costs likewise would not be reimbursable.

By contrast, enhancement expenditures are made to improve conditions beyond those that could be predicted in the absence of the project. Any non-federal interest, not just project sponsors, can contract with the Federal government to share the costs of such environmental initiatives, even though the wildlife benefits may be strictly local. Generally, if the project sponsor or other interest agrees to repay one-fourth the cost of enhancement the Federal government bears the cost of the balance. 9/

One current debate centers around who should pay when a project is constructed, repayment contracts have been entered into, and mitigation is later called for. This was the problem we recently encountered with the Palmetto Bend Project (Texas). The Interior Department agreed to seek legislation making mitigation non-reimbursable. In these situations, if project water users have already agreed to repay a fixed obligation which does not include the costs of providing such later-added mitigation, then we are presented with the problem of awaiting an agreement to repay during contract renegotiation (before which no mitigation can be installed), or seeking a Congressional waiver of the reimbursement requirement. 10/

The whole question of whether mitigation costs should be reimbursable is still being debated. Because the reimbursement requirement often puts project sponsors in a position of opposing mitigation, some argue that such confrontation can be eliminated, and Federal mitigation goals more readily met, if reimbursement is waived. Indeed, it is common to find Congressional waivers of mitigation cost reimbursement. 11/

In non-federal projects the costs of recommended mitigation can, as a practical matter, determine whether mitigation will be adopted. At least for larger non-federal projects, perhaps there may be cases where the costs of mitigation should not be borne totally by the private developer, any more than they are by federal water project sponsors. There can be ample justification in some cases for a joint Federal-State-privately funded conservation program, particularly where enhancement is also involved.

HOW FEDERAL LAW OPERATES TO REQUIRE MITIGATION

By the 1958 amendments to the FWCA, Congress provided authority to the Federal water project agencies to modify or add fish and wildlife mitigation and enhancement measures to the structures and operations of such projects. 16 U.S.C. § 662(c), 663(c), 662(g). So, by that time, fish and wildlife "purposes" were added to the other "purposes" for which federal water projects could be planned and operated. And the "lack of authority" for mitigation-- which often frustrated mitigation planning--ceased to be an issue on most authorized water projects. 69 I.D. 224 (1962). Similarly, the FWCA has been construed to authorize other agencies to deny Federal permits or licenses for failure to mitigate. Zabel v. Tabb, supra.

There is, of course, a difference between an authority to mitigate and a requirement to mitigate. For example, the FWCA contains a directive that water project plans "shall: contain mitigation measures deemed justified by the construction or licensing agency. 16 U.S.C. § 662(b). Does it follow that once consultation is completed, the agencies must mitigate, or must they mitigate only where they think it is justified?

8/ Section 6(b) of the Act of July 9, 1965, 79 Stat. 216 (16 U.S.C. 460l-12, etseq). The FWPRA also amended the FWCA to prohibit future planning for Federal assumption of certain kinds of enhancement costs. See 16 U.S.C. § 662 (d).

9/ Section 460 l-13, Title 16, U.S.C.

10/ See Water and Water Rights, supra, n. 6, at § 123.

11/ Canadian River Project (Texas), 64 Stat. 1124 (1950); Baker Project (Oregon), 76 Stat. 634 (1962); Colorado River Storage Project, 70 Stat. 110 (1956).

NEPA requires federal agencies to "use all practicable means" to avoid environmental degradation, and to preserve "natural aspects of our national heritage" to the extent consistent with "other essential considerations of national policy." 42 U.S.C. § 4331(b). The courts have consistently held that it is insufficient for a federal agency to give lip service to an environmental review requirement and then to proceed in blissful disregard of its requirements. 12/ Accordingly, the Courts hold that NEPA requires federal agencies to effectuate NEPA's mitigation objectives, except when such is specifically excluded by statute or when existing law makes compliance with NEPA impossible. 13/ It has proven very difficult to make such a showing of conflict or exclusion in the federal courts. The directive to mitigate is clear, though the extent of mitigation efforts is still left largely to federal agency discretion.

There is a common law doctrine emerging that the FWCA requires mitigation plans to be developed, authorized, and implemented concurrently with other aspects of federal project plans. Akers v. Resor, 339 F. Supp. 1375, 1380 (W.D. Tenn. 1972); Texas Committee on Natural Resources v. Alexander, 12 ERC 1676 (E.D. Texas 1978).

Administrators and Courts pay a great deal of attention to the question whether continued federal action which may foreclose options for mitigation should be permitted pending compliance with other federal environmental review requirements which are designed to establish mitigation needs. Examples are the Gulf of Alaska 14/ and Baltimore Canyon 15/ OCS leasing cases, and the Tellico Dam case. 16/

One of the first cases to deal with the relationship between agencies with separate environmental reviews of a project was Citizens Committee for the Hudson River Valley v. Volpe, (Hudson River Expressway), F.2d 97 (2d Cir. 1970). That Court enjoined a Corps of Engineers' dredge and fill permit until consent for construction of a causeway on the fill was obtained from the Secretary of Transportation under 49 U.S.C. § 1655(g). The Court reasoned that one agency should not, as a practical matter, foreclose the decision of another. This view was expanded in EDF v. Froehlke (Cache River), 473 F.2d 346 (8th Cir. 1972), where the Court observed:

> Responsible critics of the project have urged that no project be initiated until a mitigation plan is actually put into effect in order to prevent easily avoidable environmental losses. They state that following the commencement of construction, it will become difficult -- if not impossible -- to acquire suitable land for mitigation because of increased property values and the continued clearing of land for cultivation. Thus, in their view, any mitigation proposal is inextricably linked to the project itself. Such a view is not clearly without merit. (Id., at 351, 352).

This idea is also expressed in the NEPA 17/ and the proposed FWCA rules, 18/ as well

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12/ See cases cited in Public Service Company of New Hampshire v. NRC, 582 F.2d 77, 81 (1st Cir. 1978); Zabel v. Tabb, supra.

13/ Id.

14/ Alaska v. Andrus, 580 F.2d 465 (D.C. Cir. 1978).

15/ County of Suffolk v. Secretary of the Interior, 562 F.2d 1368 (2d Cir. 1977).

16/ T.V.A. v. Hill, 437 U.S. 153 (1978).

17/ 40 C.F.R. § 1506.1 provides:

> (a) Until an agency issues a record of decision as provided in § 1505.2 (except as provided in paragraph (c) of this section), no action concerning the proposal shall be taken which would:
> (1) Have an adverse environmental impact; or
> (2) Limit the choice of reasonable alternatives.
> (b) If any agency is considering an application from a non-Federal entity, and is aware that the applicant is about to take an action within the agency's jurisdiction that would meet either of the criteria in paragraph (a) of this section, then the agency shall promptly notify the applicant that the agency will take appropriate action to insure that the objective and procedures of NEPA are achieved.
> (c) While work on a required program environmental impact statement is in progress and the action is not covered by an existing program statement, agencies shall

as the Endangered Species Act (ESA) rules. 19/ I will discuss here only how the ESA deals with mitigation disputes because, in the 1978 Amendments to the ESA, the Congress endorsed our approach to resolution of mitigation disputes, as stated in our ESA regulations and our argument in the Tellico Dam case.

The ESA makes a critical distinction between loss prevention and other measures designed only to reduce or minimize impact. Section 7 of the ESA requires federal agencies to (1) engage in affirmative conservation programs for endangered and threatened ("listed") species, (2) insure against adverse modification or destruction of critical habitat, and (3) avoid jeopardizing the continued existence of listed species.

We have determined that federal agency compliance with the directive to engage in affirmative conservation programs, including mitigation efforts, does not supplant the Section 7 requirement to avoid destruction or adverse modification of critical habitat or jeopardy to the continued existence of a species. 20/ This aspect of the ESA was reaffirmed by the 1978 Amendments to the ESA, which created an Endangered Species Committee with authority to grant exemptions to Section 7. 92 Stat. 3751. The amendments enacted the Department's earlier regulatory admonition against irreversible and irretrievable commitments of resources pending compliance with the ESA consultation process. See National Wildlife Federation v. Coleman (Sandhill Crane), 529 F.2d 359 (5th Cir. 1976). They direct the Secretary to recommend reasonable and prudent alternatives to consulting agencies, but not if adoption of such alternatives would run afoul of section 7. Finally, the Endangered Species Committee may grant an exemption only after mitigation and enhancement measures have been prescribed, but not because they can be. 16 U.S.C. § 1536(h)(1).

Most important, in the 1978 Amendments the Congress expressed its disfavor of bad faith negotiation on mitigation-type issues, calling instead for responsible efforts to develop and fairly consider project modifications or alternatives which avoid impacts upon protected resources. 16 U.S.C. § 1536(g)(5). It is my experience that if these principles are observed, mitigation disputes can, in most cases, be resolved short of irreconcilable conflict if the facts are laid out and contending parties show a willingness to find solutions.

CONCLUSION

I'd like to leave you with some observations about the present state, and probable future course, of federal law on mitigation.

Mitigation, and particularly its component "loss prevention," are now being emphasized as an integral part of the planning conducted before projects are authorized or approved. At least in practice, the more traditional planning approach to mitigation often involved taking resource impact as a given and designing a project to contain features which would attempt only to compensate for that impact, rather than to avoid it.

Mitigation is now being recognized as a continuing obligation, to be carried out during the implementation of a project. Moreover, mitigation will be planned for authorized projects. No longer is it permissible to stop thinking about mitigation

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(footnote 17 cont'd)

> not undertake in the interim any major Federal action covered by the program which may significantly affect the quality of the human environment unless such action:
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> (1) Is justified independently of the program;
> (2) Is itself accompanied by an adequate environmental impact statement; and
> (3) Will not prejudice the ultimate decision on the program. Interim action prejudices the ultimate decision on the program when it tends to determine subsequent development or limit alternatives.

18/ The proposed FWCA rules would require Federal agencies to require applicants for authorization issued by them to provide proof of compliance with sections 402 and 404 of the Clean Water Act and sections 9 and 10 of the River and Harbor Act of 1899, where also applicable. (Proposed 50 C.F.R. § 410.16 (b)).

19/ 50 C.F.R. § 402.04(a)(3) (1978).

20/ Section 7 is to be contrasted with the FWCA or Section 4(f) of the Department of Transportation Act, which ultimately permit inroads into resources protected by those statutes where loss reduction measures do not remove the threat.

once the agency or congressional approval process is completed.

Much more attention is now being devoted to annual appropriations requests for operation, maintenance, and repair (OM&R) of mitigation measures. Many policy-makers now recognize that if mitigation features are adopted but not operated and maintained during the life of the project, we will realize little, if any, of the mitigation which helped justify the project in the first place.

NEPA requires us to examine the direct, indirect, and cumulative impacts of a project, wherever they occur -- not just in the immediate project area. This is particularly important in such areas as aquatic habitat analysis, where the downstream effects of a water project can often potentially exceed the on-site impacts. The open question is: at what point do indirect or cumulative effects become so remote that mitigation therefor should not be required.

We must recognize the "without-the-project" baseline assumption used in recommending mitigation and enhancement measures. It is from this baseline that the degree of project impact, and hence the degree of mitigation required, is measured. It is particularly important that this baseline computation be accurate because the costs of mitigation and enhancement measures which have been so quantified have impacts upon the federal budget and those who must repay a portion of those costs to the federal treasury.

Finally, the President has directed us to develop methods to prevent or to mitigate losses to fish and wildlife resources. He prescribed no single method. Until recently, there has been insufficient attention paid to methods for quantifying impacts on wildlife resources, as opposed to impacts on the human use of those resources. Losses and gains were traditionally measured in dollar terms related generally to man-day use figures, because of the need to calculate monetary benefits and costs in order to obtain Congressional approval of the project.

Human use and wildlife resource productivity do not always correlate -- and, in fact, often directly conflict. Yet low human use figures often produced low estimates of losses and mitigation needs and high estimates of gains produced by project features, with neither bearing much relation to what fish, wildlife, and their habitat were lost or gained.

If wildlife resource productivity is to replace human use as the measure of project impacts and mitigation gains, the development of methods to quantify wildlife resource productivity will be your biggest challenge. In this era of escalating competition for limited resources, decisions will be based increasingly upon carefully considered and justified quantification of resource needs.

Thank you.

Refitting Noah's Ark: Adapting an Ancient Technique to New Problems[1]

Jane H. Yarn[2]

Mitigation is certainly not a new concept. Perhaps the first example was Noah and his ark -- and there are certain interesting parallels to our current work. You will recall that Noah was instructed by God to bring two of each kind of species aboard the ark -- not just the majestic ones, or the graceful ones, but also the ugly or less appealing ones. This is perhaps the first recorded example of a truly ecological insight: a recognition that all wildlife is interrelated, and nothing is without value.

The purpose of the entire ark enterprise, of course, was to mitigate the bad effects of the world's first -- and still the world's largest -- water project.

But in citing the great flood, we must not fall into the trap of regarding mitigation as something good to compensate for something damaging. A modern concept of mitigation must go far beyond the idea of reducing damage after it has occurred. We must learn, instead, to think of mitigation as a preventive measure where possible -- to prevent the damage from happening in the first place.

I would argue that mitigation has three aspects, the first being what we might call "disaster modification." This is the Noah's ark brand of mitigation -- trying to salvage what we can from a project over which we have little control. Examples of this might be protecting the American buffalo after it was almost extinct, raising and releasing the Peregrine falcon, and many of our endangered species protective programs. That's all very good, but it's not enough. We need to prevent species from becoming endangered in the first place.

A second kind of mitigation is the compensatory kind: if a project requires the destruction of 100 acres of habitat in one place, the project supporters must come up with 100 acres of similar habitat somewhere else. This concept has been recognized in law for some time, but it has been violated as often as it has been honored. Too often the 100 "compensatory" acres have been ecologically inferior to the 100 acres destroyed as well as totally inappropriate for the kinds of creatures that lived in the old habitat.

Even if the "mitigation" habitat is similar to that which is destroyed, it usually is already occupied by an existing natural system of plants and animals. We should not make the mistake of assuming that wildlife communities, any more than human communities, can be displaced by development and survive intact elsewhere.

There is some creative work going on with compensatory mitigation, however -- creative solutions that blend biology with economics. In Los Angeles, for example, the Port Authority wanted to fill a 10-acre slip to provide storage for containerized cargo. The fill would have been provided by dredge spoil from the main channel -- and that, in turn, would have destroyed the habitat of some bottom-dwelling organisms that feed fish. Appropriately, the Fish and Wildlife Service and the California Fish and Game Commission demanded that the Port compensate for the damage with new habitat elsewhere.

Considering the price of 10 acres of waterfront property in Los Angeles, that would have been very expensive habitat indeed. But Calvin Hurst, Environmental Director for the Port, got the Federal and State officials to agree to an experiment: an attempt to create a kelp bed inside the breakwater in a relatively isolated part of the Harbor. It worked. The plants have spread 300 to 400 feet and have provided habitat for hundreds of species of fish and invertebrates.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Member, Council on Environmental Quality, Washington, D.C. 20006.

The third kind of mitigation is sometimes the most difficult, but it is also the most important: preventing damage from occurring in the first place. This is done by bringing mitigation into project planning right from the start, so that it is a working principle rather than a half-hearted set of measures to slip a project past the environmental censors.

For example, the Carter Administration has taken several steps to insure that greater consideration is given to fish and wildlife in the planning and construction of federal projects.

In his water policy message of June 6, 1978, President Carter directed Federal agency heads to "implement vigorously" existing environmental statutes. He specifically ordered the preparation of formal implementing procedures for the Fish and Wildlife Conservation Act and the Natural Historic Preservation Act.

Recognizing that mitigation measures for past federal projects have sometimes been "too little, too late," the President also directed agency heads to include funds for mitigation in water project appropriations requests "to provide for concurrent and proportionate expenditure of such funds along with project construction funds."

CEQ has also sought to insure this kind of advanced planning and integration into decisionmaking in the environmental impact statement process. We do not want impact statements written after projects are entirely designed, as justifications for decisions already made. Our new regulations, which go into effect at the end of this month, have been designed to eliminate "after-the-fact" rationalizing.

Specifically, the new regulations make two major reforms in the ways in which agencies are to meet mitigation requirements. First, in response to many years of requests from agencies for CEQ advice on what mitigation really means, the new regulations contain a comprehensive definition of the term. In the regulations, the term "mitigation" includes: (a) avoiding the impact altogether by not taking a certain action or parts of an action; (b) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (c) rectifying the impact of repairing, rehabilitating, or restoring the affected environment; (d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action, and (e) compensating for the impact by replacing or providing substitute resources or environments.

Second, the new regulations require that mitigation be included in agencies' final record of decision when an EIS has been prepared on a proposal. The relevant section states that the record shall "state whether all practicable means to avoid or minimize environmental harm from the alternative selected have been adopted, and if not, why they were not. A monitoring and enforcement program shall be adopted and summarized where applicable for any mitigation."

This new requirement for an explicit monitoring and enforcement program to carry out mitigation is bolstered by a further requirement that the lead Federal agency shall "upon request, inform cooperating or commenting agencies on progress in carrying out mitigation measures which they have proposed and which were adopted by the agency making the decision."

These provisions go a long way toward making concrete the good intentions so frequently but often vaguely stated by federal agencies.

The new regulations require that this principle of thinking before we act, rather than trying to repair the damage after it has occurred, must be broadly applied -- not only to water projects but to urban developments, energy projects, and a range of other land use proposals.

But how do we assign relative values to our natural resources? What is the dollar value of development? It is difficult to find much agreement on this subject. Ecologists debate and dispute the figures put forth by other ecologists. Economists challenge methods and results. Meanwhile, the dollar signs continue to appear in the literature. For example, at present market value, the timber productivity of Georgia's Alcovy River system is estimated at over $1,500,000 per year, or over $600 per acre. As a sediment filter alone, the Alcovy River swamp is valued at over $3,000 annually and for water quality alone the River's 2,300-acre swamp ecosystem at $1 million annually. These figures do not even reflect the wildlife values or recreational, aesthetic and "visual-cultural" values.

In developing a wildlife impact assessment which will be used to determine mitigation measures, the Council strongly supports basing the assessment on the quality and productivity of the habitat actually being affected, rather than using any predetermined formulas, such as "man-day use." If we can refine and adopt scientifically sound habitat evaluation procedures, we will come closer to recognizing the real values of some of our natural resources.

One key to recognizing resource values is through informing ourselves and the public. To that end, the Council on Environmental Quality is about to release an important task force publication, titled Our Nation's Wetlands, which we hope will provide readers with a scientific, social, and political understanding of our current wetland policies and concerns.

We look forward to the time when we can routinely expect careful thought and environmental planning to precede action. It is a concept that must apply to all our future development -- to our energy policy as it responds to the need for new programs, to transportation, to new urban and rural developments, and to a host of other programs. We no longer have such an abundance of resources that we can expect nature to compensate for or erase our technological mistakes.

I am reminded of a story I once heard about a little boy who decided to confront a wise, old man. The boy took a small bird in his hand and put it behind his back. He planned to pose to the wise man the following questions: What do I have in my hand? Which hand is it in? And, is the bird dead or alive?

If the wise, old man answered correctly on the first two questions, he would surely fool him on the third, for if the man guessed the bird to be dead, he would bring it forward alive. And if the man guessed the bird to be alive, he would squeeze it tightly and bring it forward dead.

And so the boy posed the questions. And the old man guessed it to be a bird, and also guessed the proper hand. And when the little boy asked if the bird was dead or alive, the wise old man replied: "My son, the answer to that is in your hands."

And so it is with mitigation. The answer is in our hands. Through efforts like this symposium, through management techniques and through regulations, we can seek to resolve conflicts involving our finite resources. As we continue our pursuit of food, of shelter, of recreation -- as we push our resources to the very edge of their, and our, survival -- we must insure that mitigation becomes an essential element of everything we do. There is really no other choice.

Mitigation: The State's Viewpoint[1]

Jack H. Berryman[2]

Abstract.--As the fish and wildlife resource managing agencies, the states are concerned with habitat loss and efforts to mitigate losses. They believe the costs of pre-planning studies and post-development operation should be part of project costs. They are dissatisfied with mitigation, federal coordination, increasing "federalism", needless delays, and continued losses.

The International Association of Fish and Wildlife Agencies is composed of the state, provincial, and federal fish and wildlife agencies, generally of North America. It represents those agencies on matters of collective interest. Mitigation is one of those matters. It is the fish and wildlife agencies that have the public trust responsibility for managing the fish and wildlife resources that are most directly affected by habitat losses. It is the fish and wildlife agencies that are most directly concerned with the effectiveness of measures to mitigate those losses. So, we are much concerned and much involved.

It would be difficult for me to express a new and startling viewpoint on behalf of the state fish and wildlife agencies on the subject of mitigation. These views have been rather thoroughly documented by resolutions of our Association in 1965; in 1967; in 1968; in in 1969; in 1972; and in 1975;[3] by participation in the Coordinating Committee which produced the "Action Report" of September 1971; in testimony before Congress, especially in 1974 and again in 1978.[4] And, the chronological, legal, and philosophic history; the details; and the progress of mitigation will be traced by the many papers to be presented here.

I can, however, point out some of the reasons for the states' deep-seated concerns, place these in a current perspective, and relate the subject of mitigation to the complex of issues and events which confront state administrators and wildlife managers.

First and foremost, we recognize that habitat modification, reduction or loss is the principal physical factor governing fish and wildlife resources -- whether it be riparian, wetland, upland or marine -- or whether changes are brought about by dams, drainage, urban encroachment or environmental contamination. We recognize that modification usually means losses for some species and gains for others -- not always "tradeable". However, the greatest concern is with irreplaceable loss, and we know, of course, that mitigation implies loss.

Realistically, we recognize that society's competing demands will increase the pressures upon prime fish and wildlife habitats. We are in a new period of resource use, with increased demands for food and energy -- and with these resources being used as diplomatic tools in struggles for national survival.

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[1] Paper presented at The Mitigation Symposium, A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Ft. Collins, Colorado, July 17, 1979.

[2] Executive Vice President, International Association of Fish and Wildlife Agencies, Washington, DC

[3] All in the published Proceedings of the Association's Annual Conventions.

[4] Hearings before Subcommittee on Fisheries and Wildlife Conservation and the Environment, June 26, July 1, 2, and 11, 1974; and July 26, 27, and August 10, 1978.

Moreover, the state fish and wildlife agencies do not control or manage more than an infinitesimal fraction of the habitats so necessary to the well-being of the fish and wildlife resources they are responsible for managing. Gross changes in habitat are brought about by national and international policies, by county and state boards and agencies, and by public and private developers. The successful agency must work with all of these forces.

The International Association of Fish and Wildlife Agencies is committed to the principle of balanced, rational resource use -- not just of fish and wildlife resources, but the balanced use of all resources. That being the case, we recognize that all decisions will not favor fish and wildlife habitat -- that habitat will frequently be secondary to a host of other human requirments -- power, food, energy, urban and industrial development.

But, we recognize also, that it will be a losing game unless these needs are carefully and objectively analyzed and unless fish and wildlife resources are considered as a necessary component of the future American scene. We must insist that the planners, the proponents of development and the other resource users also embrace the philosophy of balance.

As the wildlife manager must accept balance, so too must the developer recognize that the protection and maintenance of fish and wildlife habitat must be an integral part of the plan, design, and cost of every project. It has been the lack of this recognition and a callous disregard that gives impetus to extreme preservationist movements -- the opposite swing of the pendulum.

So, the state agencies are indeed interested and vitally concerned with mitigation or enhancement as tools for maintaining habitat in a fiercely competitive contest for the use of finite land and water resources.

Quite simply, they know that every land and water use affects fish and wildlife, and they want those effects considered in all land and water uses, from suburban backyards to major water, irrigation and power developments. The states tire, however, and resent mitigation rhetoric, quibbling over definitions, agency struggles, legal niceties, bureaucratic obstructions, and delays. I might add, that the resolutions mentioned earlier have not been satisifed.

When it is necessary to modify or destroy habitat, they rightly expect but can only hope and fight to have the loss offset -- promptly and as realistically as possible. Ironically, it is frequently the most valuable fish and wildlife habitat that is most subject to other uses -- riparian, estuarine, wetland, etc. And, they know that in spite of the rather belated progress that has been made, mitigation has not been working.

In spite of the various efforts of the past three decades, the losses continue. More and more and more habitat is lost each year. Look at the record -- the salmon runs, the potholes, the southern hardwoods, and it goes on and on and on.

A cardinal belief of the states is that the costs of protecting, compensating, or mitigating fish and wildlife losses should be considered part of project costs. That principle is well established in dealing with privately owned capital investments -- when public projects damage private lands, buildings, or other property. It is far from established when public or private projects damage fish and wildlife resources. Perhaps this is because fish and wildlife resources are "public goods", in economic parlance. Until this principle is fully accepted, mitigation will continue to be a losing game.

The state fish and wildlife agencies have long sought federal funding to evaluate proposed federal development projects; also, to manage and maintain lands after project completion. There are two points to be made here. One is a matter of principle; the second relates to state planning and budgeting; and to increasing federalism.

We believe, as a matter of principle, that the cost of evaluating project effects upon fish and wildlife resources and developing a design to include fish and wildlife benefits is part and parcel of project design and project costs. It should be considered in the same vein as hydrologic, geologic, topographic, and engineering surveys. And, implementing the plan for fish and wildlife may be likened to the costs of dam construction and the continued maintenance of the water control structures. But, here the analogy ends. The studies should be financed by the federal government or project beneficiaries, but carried out by the state fish and wildlife agencies which will (or should) assume management responsibilities with money from project funds.

Increasingly, state agencies are called upon to undertake responsibilities which result from federal actions, either legislative or executive -- usually without accompanying funds, or which require matching funds that strain already tight budgets. Obvious examples are the National Environmental Policy Act and the Endangered Species Act; executive orders on animal damage control; international treaties such as the Convention on International Trade in Endangered Species; not to mention the non-resource related requirements of the Occupational Safety and Health Administration or Equal Opportunity. Each of these and countless others set standards or requirements or impose responsibilities upon the state agencies that require substantial expenditures of funds and time. In the absence of funding, the states must re-order their priorities to accommodate either a federal mandate or in response to federal actions. Quite often this is at the expense of critical, planned, and budgeted work that state personnel believe is of higher priority. The point is, of course, that this kind of federal action sets state priorities for the expenditure of state funds. This is one of the reasons the states resist this kind of increasing federalism; it is one of the reasons that states demand funding to evaluate water projects and operate management areas. Water development projects also create other situations that must be handled by local and state governments -- increased use, enforcement, etc. It is sort of a double whammy.

Right now there are approximately 11,000,000 acres of Corps of Engineers lands suitable for fish and wildlife oriented recreation and management by the states. Unless authority and funding are forthcoming, preferably via the Congress, state management will go by default and pressures will develop for private concessionaires.

Great stock and hope has been placed in strengthening of the Coordination Act by the issuance of tight regulations. This Association is a supporter of that effort. In fact, we joined the National Wildlife Federation and others in asking Congressman Oberstar to delay introducing legislation until the long-awaited regulations were out. Well, they are out. In fact, the comment period ends today. While they are an improvement, they contain some weaknesses. It is doubtful whether strengthened regulations can clear the whole gamut of the federal system. Already organized opposition is developing -- obstacles, delays, etc. It may be necessary to go the tough, legislative route.

The states are disillusioned with federal mechanisms for coordination. It had been hoped that the Council on Environmental Quality would help resolve conflicting federal policies and activities. This was the idea when that agency was set up -- independent and answerable to the President -- as an advisor on controversial major environmental actions and as a referral mechanism. Unfortunately, that has not been the case to the present time in the wildlife area. While whole river systems and river valleys were lost, CEQ devoted its considerable influence but limited resources to single species issues, such as the status of the bobcat and other relatively minor issues. We hope that under new leadership that agency will become more active in major issues and in improving federal coordination -- and in support of realistic mitigation. We will support such a redirection. There is also the hope that CEQ's new regulations on NEPA, effective this month, will be helpful.

To summarize, the states view the maintenance of habitat as a survival issue and the realistic mitigation of any necessary loss as an absolute necessity. They hold to the principle that the costs of evaluating impacts upon fish and wildlife resources, the costs of mitigation, and the costs of post-development operations are all normal costs of any land or water development project. They are not satisfied with mitigation to the present time. They are not convinced that the proposed Coordination Act regulations will provide the needed remedy, and they are dissatisfied with federal coordinating mechanisms. There is reason for optimism -- this symposium, the President's initiative on a National Water Policy, new environmental laws, a more receptive public and, hopefully, a Congress that will continue to be responsive.

But, until the states see something more tangible than the empty promises of the past, they will continue to be skeptical. We hope that these discussions will be another step toward the resolution of what has been a nagging dilemma and a severe wildlife conservation problem.

The Role Of Private Conservation Organizations In Mitigation[1]

Patrick A. Parenteau[2]

Private organizations have been active in America's wildlife conservation programs since very early in our conservation history. It was at the urging of the American Fish Cultural Society that the U.S. Fish Commission was established in 1871, and the American Ornithologists' Union was instrumental in securing in 1885 the first appropriation for wildlife work, initiating what became the Bureau of Biological Survey, and later the Fish and Wildlife Service.

The important state and federal wildlife legislation, of the turn of the century and soon after, was the result of aggressive efforts of such organizations as the Boone and Crockett Club, the early Audubon Societies, the Camp Fire Club of America, and the American Game Protective and Propagative Association. And the efforts of these organizations continued through the years.

In the 1960's and '70's, however, a challenge emerged which was stronger than conservationists had ever met before. The nation's water, soil, and air was being polluted at an accelerated rate. Persistent pesticides such as DDT and its chemical cousins were being distributed from the air over hundreds of millions of acres. Government and private development projects were destroying or degrading fish and wildlife habitat at a rate never before experienced. And the official conservation agencies, established to protect the public interest, seemed unable, and sometimes unwilling to try, to halt or slow the destruction. Selfish commercial interests clearly had the upper hand.

Many well-intentioned laws were passed by Congress and the States, but they were often ignored. To meet this critical situation the environmentalists grasped for a tool they had scarcely ever used before, litigation, and the threat of litigation. If logic and gentlemanly persuasion fails, take it to court. It is by this means that some of the most significant conservation battles have been won, and a new strategy established.

The war has not been won. There are many battles ahead. But it is no longer possible for the forces of habitat destruction to assume, as they did, that they can do as they please.

Mitigation of habitat losses is a particularly important case in point. The intent of the Congress, as expressed in the Fish and Wildlife Coordination Act, was that fish and wildlife resources should get equal consideration with other uses when a federal project was proposed, authorized, planned, and constructed. But the law was largely ineffective until citizen conservation organizations made their influence felt. There are several such groups that deserve a portion of the credit, but I'll use the National Wildlife Federation to illustrate my points.

We have made mitigation an issue in the 1970's. Prior to that time the construction agencies' cavalier attitude toward their fish and wildlife responsibilities had gone unchallenged. The Fish and Wildlife Service and their State counterparts had been compromised early in the project authorization process. Citizen groups brought the shortfalls to light in key cases across the country.

Based upon such experiences the Federation formally petitioned the federal agencies for regulations for mitigation on water projects -- regulations which had never been promulgated though the Coordination Act was last revised in 1958. Without the regulations which the Act required it could not be expected to serve the purpose Congress intended. President Carter responded by calling for the regulations in his Water Policy Message of May, 1978, and finally, on May 18th, 1979, the proposed regulations, duly signed by the Secretaries of the Interior and of Commerce, appeared in the Federal Register and are available to us for review and comment. I hope that the members of this Symposium will study and urge adoption of the regulations.

For justification of federal water projects the methods employed for calculating the benefit/cost ratio have been thoroughly unsatisfactory.

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[1] Paper presented at The Mitigation Symposium, July 16-20, 1979, Fort Collins, Colorado.

[2] Director, Resources Defense Division, National Wildlife Federation, Washington, D.C.

The wildlife costs and benefits have been based upon the conceptually-flawed and outmoded man-day use method, giving the hunter or fisherman man-days of use a dollar value. The short comings of this method have been obvious. You cannot replace fish and wildlife losses by moving sportsmen around. The man-day method focuses upon users, rather than resources, subverting the intent of the Coordination Act.

It also focussed almost exclusively upon the sportsmen, the consumptive users of the area, omitting the growing host of non-consumptive users, the hikers, birdwatchers, and photographers, whose numbers are growing far more rapidly than the sportsmen's. The Federation took a lead role in urging reforms of the benefit/cost procedures, and when adopted they will evaluate the full costs and benefits of a water project, essentially for the first time.

In many cases we have found it necessary to resort to litigation to protect precious wildlife values, but our clear preference is negotiation leading to administrative solutions. When administrators find that the Federation and its sister citizen groups are able to litigate, and win, they often discover that they can do something for wildlife, and we can leave litigation as a last resort.

An excellent example of persuasion, not litigation, involved the Bachman's Warbler in South Carolina. The last confirmed sightings of this endangered species were several years ago in and near the Francis Marion National Forest. It seemed likely that if the species still exists, and it has any chance of surviving, it will be on this National Forest, and that it will require modification of the "normal" forest management plan. When the situation was brought to the attention of the Forest Service the Service agreed to participate in the necessary studies and to include in their management plan for the Forest everything that was known to favor the warbler.

Obviously this route is preferable to litigation, but all too often the wildlife agencies have been maneuvered into a position where the only option open is the courts. In such cases the citizen conservation organizations have often played the key role. In some of the recent cases in which the NWF has participated successfully the authority of the Endangered Species Act was involved, rather than the Coordination Act.

Most widely publicized was the case of TVA's Tellico Dam in the Tennessee River, which, if closed, would have inundated, and destroyed, the stream habitat of the rare Snail Darter. The Supreme Court decided against the TVA and in favor of the Snail Darter. Rallying cry of the developers asked "Is an insignificant 2-inch fish worth $105 million (the total cost of the dam and the land it would flood)?" The lobbying power of the development interests in Congress was so strong that this case resulted in an amendment to the Endangered Species Act, establishing a Cabinet-level commission to consider "exceptions" like the Tellico Dam Case. The Commission, however, ruled against Tellico, not only on the grounds that it would destroy the tiny fish, but that it was totally unjustifiable economically, even though 70 percent of the costs had already been spent. The National Wildlife Federation guided all of the maneuvers through to the successful conclusion.

Another precedent-setting case, unique thus far in the United States, was that of the Grayrocks Dam in southeastern Wyoming on the Laramie River. A dam on this important tributary of the Platte River will affect the habitats used as staging areas by hundreds of thousands of Sandhill Cranes and waterfowl, and of key importance, of the endangered Whooping Crane as well. In October, 1978, NWF won the Grayrocks suit, and in December, 1978 entered into a unique settlement which establishes a $7.5 million trust fund for the acquisition of water rights and the operation of a management plan to protect crane habitat on the Platte River for future generations.

Another case involved the Mississippi Sandhill Crane and Interstate Route I-10 in Mississippi. An NWF suit in 1975 challenged a federal highway bisecting habitat of the endangered crane. A favorable decision on appeal in 1976 enjoined the most damaging aspects of construction, pending negotiations over acquisition of a crane refuge. In November, 1976 the Supreme Court denied review of this decision. In 1978 the Congress authorized $4.5 million to acquire the crane refuge, allowing the highway to proceed in a modified route which did not jeopardize the cranes.

These are a few of the dozens of important cases in which the NWF has won victories for wildlife habitat. Habitat losses have been prevented, mitigated, or replaced. Fully half of the legal actions in which the NWF has been involved are of the"generic" variety, seeking to reform federal programs, particularly those which cross state or even federal boundaries, and to establish favorable precedents which will make the job easier in the future, and which will make litigation unnecessary, and administrative solutions more likely. There is no way to total the habitat saved by this means, or the resources protected.

But NWF is also involved in site specific legal actions, to save particular resources of national importance. Here it is possible to make a rough sort of tally of the acres saved. These are only a few recent examples:

--Up to 200,000 acres of bottomlands in western Tennessee (Obion);

--Up to 60,000 acres of prairie pothole wetlands in North Dakota (Channel A);

--Up to 20,000 acres in mitigation in Georgia and South Carolina (Russell Dam);

--Up to 230,000 acres of bottomlands, at least 70,000 in mitigation (Cache);

--Up to 525,000 acres of bayous and bottomlands (Atchafalaya);

And many more.

The National Wildlife Federation began its Resource Defense program in 1971, to combine our knowledge of and abiding interest in natural resources with the use of law. We now have eight lawyers in the program, plus supporting staff. In addition to the legal defense work described here the program includes educational activities, professional training, and research grants to expand its influence. The Resources Defense program has become an important service to the natural resources of our nation, and to the 3½ million NWF members and supporters.

Agriculture and Mitigation[1]

R. Neil Sampson [2]

Abstract.--Agricultural producers view mitigation with some animosity, because it competes for the use of agricultural land. The public values in preserving agricultural land are going to increase, making new and innovative mitigation techniques imperative.

INTRODUCTION

The mention of mitigation in agricultural circles conjures up a wide range of attitudes--most of which are hostile. At issue is land, the very basis of all agriculture and, for that matter, wildlife habitat. Most of the time, agriculture and wildlife can live in constructive harmony, but some of the time that is just not possible. When that happens, and there is head-to-head competition for the same piece of land, we need to be able to think clearly about the issues involved and the points of view on both sides of the issue.

We have had these confrontations in the past, but it is clear that they are going to be more frequent--and more seriously contested--in the future. Let me tell you why.

Land is rapidly becoming a limiting factor in American agricultural production. That is an historical first, and one that we don't yet know how to deal with as well as we might. Each year, America loses more than 3 million acres of farmland to development, and soil erosion reduces productive capability by an amount equal to at least another 3 million acres. That is the equivalent of losing a section--640 acres--one square mile--every hour of every day of the year.

THE LOSS OF FARMLAND

To get some idea of the magnitude of the current deterioration of the American farmland base, it is necessary to analyze and combine the major factors causing the land to lose productivity. It is not as simple as measuring the depth of the water in the well to see if it is dropping or holding steady. The farmland resource is a gigantic, complex one, with over 20,000 different kinds of soil used for the growing of crops.(1) Statistical indicators are often lacking, or are difficult to compare with each other, or hard to interpret accurately. But there are enough indicators to provide better insights than ever before, thanks to the accelerated work being done by the Soil Conservation Service in their land inventory and monitoring efforts.

The two main causes of productivity loss are soil depletion and the conversion of farmlands to other uses. Both can be reversed by man, but at such costs that it is prudent to consider both, for practical purposes, permanent.

Preliminary data from the 1977 SCS National Resource Inventories (2) gives some insights into the erosion loss from the lands currently used as cropland. The survey uses a broad definition of cropland, including row crops, close-grown crops, rotation hay and pasture, occasionally improved hayland, native hay, summer fallow, orchards, vineyards, bush fruit, and "other".

On the 413 million acres included in this "all cropland" category, SCS estimates an average annual sheet and rill erosion loss of some 2 billion tons of soil. Predictably, the rates of erosion are least on the Class I lands (just under 3 tons/acre/year average) and highest on the Class IV and VI lands (averaging from 9 tons/acre/year on all Class IVe cropland to a high of 30 tons/acre/year on Class VIe row-cropped land).

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[1] Paper presented at The Mitigation Symposium, Fort Collins, Colorado, July 17, 1979.

[2] Executive Vice President, National Association of Conservation Districts, Washington, D. C.

But what does this mean in terms of land loss? How important is a ton of soil, anyway? There are few satisfactory estimates available. So many different situations exist that it is difficult to generalize. But we can draw some conclusions from this information by converting tons of soil loss into acre-equivalents of productivity loss.

A 4-inch layer of topsoil weighs about 650 tons per acre. Although this will vary for each kind of soil, let us assume that the loss of 4 inches of topsoil will badly compromise the productivity of most cropland, if not make it totally uneconomic to farm. Obviously, there are soils where this will not be the case, but there are many soils in America today that are already badly damaged by past erosion, and another 2-3 inch loss will mean the emergence of rock, clay, hardpan, or other subsurface layers that will limit intensive cultivation.

Thus, it seems reasonable to equate the loss of 650 tons of soil to the loss of one acre-equivalent of cropland productivity. The fact that the soil loss is spread over many acres makes it no less a loss, it only changes the shape of the time-curve on which a specific parcel of land will become totally unproductive.

Table 1. Total annual soil loss to sheet and rill erosion, converted to acre-equiv. of productivity lost from American cropland, by capability class.

Cap. Class	1977 Crop (acres)	Ann. Soil Loss(tons)	Prod. Loss (ac/equiv.)
I	31,529,000	91,244,000	140,000
II	187,702,000	709,722,000	1,091,900
III	131,710,000	709,388,000	1,091,400
IV-VII	62,226,000	506,603,000	779,300
Totals	413,167,000	2,016,957,000	3,102,600

One fact becomes immediately apparent from Table 1, and that is that two-thirds of the productivity loss being sustained by America's cropland today is coming from the Class II and III lands that make up the bulk of our cropland resource. At the same time, it is clear that the marginal croplands are suffering erosion losses at a far more rapid rate. Class I land, about 9.5 percent of the cropland, only suffers about 4.5 percent of the productivity loss. Equivalent ratios for the other classes of cropland are: Class II--45% of the cropland, 35% of the loss; Class III--32% of the cropland, 35% of the loss; and Classes IV-VII--15% of the cropland, 25% of the productivity loss. This is not surprising and is, of course, what one would expect to find. Recent trends in farmland use show that farmers have been slowly, but steadily, moving off the marginal (Class IV-VII lands) in favor of the better farmlands. These erosion figures leave little doubt why; the marginal lands are washing out from under the farmers.

When we look at the land lost to urban, built-up, and water storage areas, we get an estimate of acres moved out of the cropland inventory on an immediate and fairly permanent basis. Instead of the insidious, unseen losses from erosion that rob productivity so slowly that few notice, the conversion of a tract of prime farmland from corn to houses is clearly apparent. In the period from 1967 to 1975, it was estimated that about 5 million acres of cropland was lost in this manner, or about 683,000 acres a year.(3) In addition, another 1.6 million acres moved each year from cropland into "other" land, indicating that the magnitude of the impact of land use conversions on agricultural productivity is somewhere in the range of 2-3 times the actual acreage converted at any one time.

Of the land converted to urban and built-up uses between 1967 and 1975, 7 percent was Class I, 30 percent was Class II, 21 percent was Class III, and 42 percent was in Classes IV-VIII. USDA estimated that, during the 1967-75 period, the impact of this conversion affected about 5 million acres each year, with 2 million acres being urbanized, 2 million being isolated, skipped over, or in some other way made unfarmable by the urban growth, and 1 million acres going into water impoundments. (4)

In the 1977 survey, with results to be published soon, Didericksen (5) estimates the average annual acreage of build-up to be about 2.5 million acres. If the trends observed in prior years continue, and one acre is put out

Table 2. Annual losses of agricultural productivity due to urbanization, water projects, and other building activities in the United States, by capability class, in acre-equivalents.

Cap. Class	Percent Land Urbanized	Acres Affected Cropland	Acres Affected Marginal Land
I	7	350,000	
II	30	1,500,000	
III	21	1,050,000	
IV-VIII	42		2,100,000
Totals	100	2,900,000	2,100,000

of commercial agricultural production for every acre urbanized, we arrive again at the 5 million acre number. If the percentages hold similarly to those seen from the 1975 Potential Cropland Study, Table 2 would indicate the amount of loss likely to be sustained from the different land capability classes.

Not all of the 5 million acres of urbanizing land comes from cropland, or land that should be considered to have future crop-producing capability. For purposes of this analysis, a conservative estimate of the loss would be to count only those lands in Capability Classes I-III as having future cropland potential. This would mean that the annual losses of agricultural productivity (Table 2) would be somewhere in the 2.9 million acre range. There will be, of course, a small loss of cropland from Classes VI-VIII. This would be minor, however, since those marginal lands account for so little of the future agricultural productive capacity.

Adding the two estimates of the losses to productive capacity from erosion and conversion leads to Table 3.

Table 3. Estimated annual loss of United States agricultural productivity, in acre-equivalents, due to soil erosion and conversion to non-agricultural uses, by capability class.

Capability	Loss to Erosion	Loss to Conversion	Total Loss	(%)
	(Acre-Equivalents)			
I	140,000	350,000	490,000	(8%)
II	1,091,900	1,500,000	2,591,900	(43%)
III	1,091,400	1,050,000	2,141,400	(36%)
IV-VIII	779,300	0	779,300	(13%)
Total	3,102,600	2,900,000	6,002,600	

These figures represent a conservative estimate of the magnitude of the loss being sustained from the American farmland base. They are not individual and discrete acres being covered by asphalt or concrete in an absolute and permanent conversion, but they represent the productive capacity being lost each year through the combined forces of soil erosion and land use conversion.

The loss of productive capability that results from the combination of soil erosion and land use conversion is not only large, but it will get larger at an increasing rate. Not only are both processes self-reinforcing; they are also interactive.

Soil depletion is not just a steady loss. It accelerates with each increment of topsoil that is washed away, resulting in less absorbtive capacity, organic matter, and plant growth to protect the soil when rain strikes again. Farmland conversion, likewise, feeds on itself. Each plot of farmland lost breeds not only new houses that consume rural resources and services; it also creates another group of farmer-speculators who decide that the time is soon coming when the land will make more money by being sold than by being maintained as a producing farm.

The interaction between the two processes is more subtle, but no less real. As erosion eats away the productivity of the land--affecting the most marginal lands fastest--it forces more reliance on the prime farmlands of the nation. Yet these are the lands taking the disproportionate share of the urbanization and build-up, so the competition for them is growing from two directions. As good lands become urbanized and unavailable for food production, it forces agriculture onto the more marginal lands, signalling a new round of soil erosion and new pressures on the land and water base.

Not only is this rate of loss an immediate and pressing concern, but there is little reason to believe that it will not accelerate in the future. The movement of people into rural America appears to be real, with rural areas growing at a more rapid rate than urban areas for the first time since the beginning of the Industrial Revolution.

COMPETITION FOR FARMLAND

There is intense, and increasing, competition for farmland. If you don't believe that, look at what prices have been doing recently. Farmland is at historic all-time highs, increasing at a rate about 2-1/2 times faster than the rate of inflation. Farm real estate jumped 14 percent in 1978. If you believe in economic theory at all, then you can't avoid the conclusion that American farmland is in limited supply.

Ah, but you say, "Look at the crop surpluses. We're paying farmers not to grow crops this year. We have more land than we need."

Let's look at that for a minute. In 1979, USDA proposed a set-aside program to encourage farmers to reduce production since stocks were, indeed, building up again after the low levels of 1973-75. We had, since the 1974 harvest, seen 4 bumper harvests throughout the world. Historically, there have never been 5 such harvests in a row, but there was no real reason why that couldn't happen. So we have had a set-aside program for the last 2-3 years.

But I just came in off a Colorado wheat farm, and I can tell you that, while we are cutting the best wheat crop in many years, the price is strong. This crop is in demand. Why The Russian wheat crop is off 20 percent, sending strong signals through the world market, and the Colorado farmer is so directly tied to the world market that a wheat failure in Khazakstan affects him as quickly as one in Kansas.

What does all this mean? I think it means this: Americans will soon begin looking at farmland preservation as a public value for the first time in our history. We've done this for a long time with wildlife. Nobody owned the wildlife, so we couldn't treat it as a private resource and let the economic market dictate how it would be used.

The conservation community banded together to become our nation's conscience on this issue, and convinced the public that there needed to be a public concern and responsibility for the welfare of wildlife. We argued, both rightly and successfully, that the welfare of people was directly tied to the welfare of wildlife, and that it was in the public interest to protect wildlife habitat ? wherever possible and replace what we could when public actions were responsible for its destruction. We said this in law, through the Fish and Wildlife Coordination Act, and other legislation. That has been good legislation, and has served a public purpose.

But we have made no such committment to agricultural land. It could be argued that one acre of corn land was like any other, and that there are no unique or irretrievable values in an acre of corn land. It was a private resource, and we have been content to let the private market settle its fate. Perhaps agricultural values will never be the same as fish and wildlife values.

We have never felt any need to think of mitigation when an agricultural acre was lost. An Interstate Highway goes through Iowa, and 40 acres of prime farmland fall away per mile. If it runs diagonally instead of squarely with the property lines, the effect on adjoining farms will be more destructive. But was that a problem? Up until recently, the answer has been "no." That is changing, and rapidly.

We are rapidly moving to the time when public agencies will be blocked from taking prime farmland from production unless there is no other feasible alternative. And when they must take it, we will hear demands for mitigation.

The taking of agricultural water in the West is going to be treated with the same concern. It is a limited, valuable commodity, and there are national economic and social values in the food that it will produce that extend far beyond the individual farm or irrigation district. Diverting it for other uses is going to become more and more a matter of public concern.

A HISTORY OF DEVELOPMENT

Historically, of course, we have been very successful as a nation when we banded together to develop soil and water resources for agricultural production. This development has often involved manipulation of the water regime. Irrigation projects in the West and drainage in the rest of the nation have been common. That historical focus on development has been strongly supported by both private attitudes and public policies. We tackled a frontier and tamed it, and we are proud of our achievements.

But we have had to learn moderation in the process. We have had to learn that fish and wildlife are important natural resources and necessary elements in the ecological system. We have had to learn that swamps and marshes have value. Now, reluctantly, we are having to learn that the frontier is gone. Now we have to do a better job of balancing interests than ever before. This isn't going to be easy, and I think we should examine some of the factors that will make it hard, and see if we can suggest some constructive ideas.

Our first difficulty has to do with that historical perspective. For over 150 years, since the days of land grants and railroad construction, Congress has played a major role in land development. When physical barriers were encountered that would stop development, federal and state programs were mobilized to remove them. Out of these efforts came the Corps of Engineers and their Mississippi River levees beginning back in 1823, the Bureau of Reclamation that has been so important to the development of the West, the Small Watershed Program, and many others. The Interstate Highway System, justified as a defense measure, has had the most impact on development patterns of anything that has happened in the past 3 decades.

All these things were done by Congress in the name of the health, safety and general welfare of the public. Most had the express purpose of encouraging the physical development of land and water resources. In short, development and land reclamation are some of the oldest public activities in the nation. Much of this development effort was aimed squarely at improving agricultural production, and it has been successful.

You can't undo all this history in a short time. Wildlife has value, but where will it fit on a value scale when it competes directly with agricultural production? Proper management of natural resources is an important goal for most people, but how will they view attempts to change historical ways of doing business? President Carter's attempts to re-direct priorities on water projects, establish a new water policy, and create a Department of Natural Resources should hold some lessons for us. Cultural, legal, political and social attitudes developed over centuries, and economic systems and conditions that have developed with those attitudes, don't change quickly.

But that doesn't mean we are chained to the past. In agriculture, for example, I see a great deal more moderation and willingness to cooperate with reasonable environmental standards. Conservation districts have, for example, been very successful in getting agricultural interests to study nonpoint source water pollution problems, identify critical problems and areas, and agree on best management practices to solve them. It takes work, communications, and patience, but it can and is being done.

THE COMMUNICATIONS PROBLEM

We are in an age of information overkill that is making rational resource planning more and more difficult. We extol the virtues of public participation and an "open" planning process, but how are we using it? Let's think about a recent case, like the Tellico Dam. Was that a contest between a 4-inch fish and the federal dam-builders? Has the 4-inch fish won? My answer to both questions is "no." But what kind of an answer do you think you would get if you took a public opinion sampling? I'd guess you'd get a lot of "don't know's." Those who could remember the issue would probably say "yes."

Because most people only knew what the media reports said about Tellico. And the most eye-catching headlines are made by confrontation; preferably confrontation between combatants of very uneven size; and particularly when the little guy wins. So Tellico had all the elements of a great news story. The dull facts--all the problems with whether or not the inundation of hundreds of acres of prime agricultural and forest lands were justified for the amount of benefits expected from the project--were left out of the stories. But these are perhaps as important in the Tellico controversy as the Snail Darter, and deserved better attention.

We are in a quandry here. If the public is going to be involved in resource decisions, they are going to have to know enough to participate intelligently. I don't know how we are going to do that. I only know I am skeptical about the ability of the mass media to contribute much but confusion. I am not convinced that the federal project planning methods have hit on the solution yet, and it is clear that most environmental impact statements are not attracting adequate public input prior to agency decision-making. I don't know what the answer is. I just think it is one of the problems that needs a lot of attention.

One thing is clear: if I am right about the forecast I posed earlier, the public's historical lack of concern for agricultural land is shifting rapidly. Public sympathy that has favored wildlife mitigation at the expense of agricultural land will also shift. People can get awfully paranoid about food, and a couple of bad crop years will cause that feeling to surface. When it does, news accounts that blow up the "destruction of prime farmland" are going to arouse strong public reaction, even when those accounts tell only part of the story.

NEEDED: NEW APPROACHES

What does that mean? Does it mean we are heading back to the "bad old days" when it was "develop at any cost?" Does it mean that we will no longer have a responsibility for wildlife habitat preservation, and a feeling that its values must be protected? I hope not, and I think most agriculturalists feel the same way. I think what it means is that we are heading for a time when both wildlife habitat and agricultural land will have strong public support, and their fate will need to be jointly considered whenever a federal project is planned.

That may cause the conservation community to do some hard thinking about its attitudes and strategies. The unspoken motto of "not one more inch", along with skillful use of the administrative and legal processes, has been effective in protecting wildlife values. Agricultural people haven't used that strategy as well, but they are rapidly learning. If they get their act together with the same forceful thrust as the wildlife protectors, we can only look forward to a more and more destructive level of confrontation. There has to be a better way.

In the past, wildlife professionals have complained that they were not invited to sit in on the initial planning of projects and were only given an opportunity to comment after many of the options had been foreclosed. On the other side of the coin, project planners contend that wildlife people have declined to participate in early planning because they had little expertise or interest in the type of project engineering and feasibility studies that mark much of the early planning. The truth is probably, as usual, somewhere in between.

But this is a serious problem we must address. After alternative designs have been selected and many man hours and tax dollars have been spent developing a plan, it is a poor time to start thinking about wildlife. Changes are harder to make, and the situation is far more likely to deteriorate into confrontation. Early communication and cooperation is essential.

CHANGES IN FEDERAL POLICY

We believe there are some basic changes needed in federal government policy that would make mitigation more palatable to agriculture. Some of these changes might be:

1.Funding for acquisition of land rights for installation of measures to mitigate damages to fish and wildlife.

2. Greater use of non-structural alternatives to flood control.

3. Better project planning that carefully evaluates probable effects on fish and wildlife.

4. A comprehensive look by Congress at the entire wetland issue (where much of the mitigation occurs), recognizing the wide range of environmental and economic values derived from wetlands.

5. A more consistent set of policy signals in regard to agricultural production, wildlife habitat protection, soil conservation, and water use so that farmers are not encouraged to manage their land one way this year and an entirely different way next year.

6. A concerted effort to encourage more innovative ways to mitigate the loss of wildlife habitat while still retaining private ownership and economic use of the land.

MITIGATION WITHOUT PUBLIC PURCHASE

I'd like to concentrate on that last point for a few minutes. It is absolutely imperative that we do what can be done to encourage private owners to supplement existing habitat without giving up their land or the ability to farm it economically. We've scarcely tapped this idea at all. There are times it won't be possible. You can't have a marsh ecology in a wheat field. But we need to look for the opportunities that do exist.

Some years back, I was in an area where a federal dam was going to inundate a canyon that was providing winter range for a mule deer herd. Mitigation ideas proceeded along the lines of buying farmland and converting it to deer range. The farmers, predictably, resisted. To the farm owners involved, that land was an important part of their year-around operation, and they would lose more than just the land itself if the plan went through.

But there were alternatives. Those farmers needed to retire some of the marginal land from crops anyway. It would have been much better in grass and shrubs. Research in the area had demonstrated that an excellent combination of grass and browse could be retained with properly managed summer grazing of cattle. The land didn't need to go off the local tax rolls, the farmers didn't need to give up all economic use, the mule deer winter range could be enhanced beyond what had existed before, and for less tax money.

What was needed was a way for the landowner to enter into a long-term contract with some economic incentives to offset the private income he would lose by making such a shift. But we didn't have that kind of a program. So the wildlife agency finally bought the land, caught all kinds of local political flak, and now have a costly wildlife management area where, I have heard, they now lease out cattle grazing in order to retain the proper balance between grass and deer browse. I think that sort of situation needs a better answer in the future, and I'd like to propose one suggestion.

THE GREEN TICKET

NACD has been discussing an idea that we call the "green ticket." It may have as much application for wildlife habitat, wetland preservation, and mitigation as it has for soil conservation. It is an idea that would attempt to harness the private, voluntary conservation approach to a sound set of economic incentives. As you know, conservation districts and NACD have always advocated the voluntary approach to good conservation measures. We feel strongly that, when citizens enter voluntarily into an agreement, they are far more likely to carry out that agreement. People forced by government into doing things they don't want to do are not only unwilling, but ineffective.

And the case for economic incentives is clear. Farmers and ranchers are private businessmen, facing tempestuous and uncontrollable economic circumstances. They buy retail, sell wholesale, and pay the freight both ways. Their crops are dependent on the weather; their markets on world conditions, Russian wheat buyers, and OPEC Oil Ministers. The market for their crops may swing from low to high and back again in a few months time, but they can only make one set of planting decisions a year, in most cases. They are, as one recent author noted, speculators in the cornfields.

And speculators don't make good conservationists. Good resource conservation comes from consistently sound management year after year. A new set of weather and crop conditions may call for a new conservation maintenance program, and the conservation manager must be ready to provide this constant- care maintenance of the land no matter what the price of corn or wheat.

This is where the green ticket idea comes in. As we have discussed it, a farmer would enter into an agreement with the local conservation district. In the agreement, he would specify what land management and conservation measures he was going to carry out, and what harmful practices he would avoid. The district would seek the technical aid of the Soil Conservation Service to determine whether the proposed system would meet SCS standards for soil conservation, as well as any standards the conservation district would impose. When all were satisfied, the agreement would go into effect and the farmer would, for every year he maintained the agreement, be given a certification by the district. This would be his "green ticket" that would qualify him for economic incentives.

Now what might those incentives be? The federal government has historically provided cost-sharing to farmers for carrying out soil conservation practices. We might start by giving first priority to those farmers who had earned the green ticket, or who needed to build the conservation practice as one of the agreed-to measures to be installed. This way we could assure that the federal cost-sharing was going onto lands where an effective conservation system would result. We have several types of tax incentives that would be both feasible and effective. There are commodity programs where incentives could be built in, and many other possibilities.

But let's go back to my story about the deer range. What if the state wildlife agency discovered that their limited funds would cause more deer range with some kind of annual incentive payment than through land purchase. What if those farmers entered into a conservation agreement with the conservation district that included, in addition to soil conservation measures, a management agreement on the deer range. The wildlife agency could set the standards they expected and the rate of the annual "rent" they were willing to pay. The farmer could look at his own business, decide if it was right for him, and sign up voluntarily. The wildlife agency could enter into an agreement with the conservation district to provide follow-up checks to assure that the range was being managed according to the agreement, and they could cross-cooperate so that the farmer would need to keep his whole plan intact in order to get his green ticket.

On the farmland itself, the agreement might include a late spring burning or cleaning for irrigation ditches and fencerows. In many areas, this can make a significant difference in wintering success of birds. It might include windbreaks, buffer strips, or dozens of other conservation practices that have dual soil conservation and wildlife values. In short, there is no reason why the green ticket idea should not be valuable to wildlife habitat. And there is good reason to investigate it as an innovative mitigation tool.

NEEDED: NEW POLICY DIMENSIONS

These are suggestions we can think about. None of them offer full solutions to the problems that will be created as more and more uses compete for a limited supply of good land. Resource managers face increasingly difficult problems, and if I have any one message, it is that those problems are going to have to be addressed jointly and cooperatively. If we pit wildlife conservation against soil conservation, or forestry, or clean water, none will be properly addressed. We must find ways to deal with private landowners so that their private land management decisions result in sound resource use. We have to articulate the public goals in resource conservation, and mobilize public support for them.

We have to define a land ethic in America that is realistic in light of modern resource conditions, social values, and economic pressures. We have to see that new land ethic translated into realistic budgets for public programs that support resource conservation, and then we have to insist that public agencies carry out those programs skillfully, effectively, and without undue cost.

We have to see ourselves as a community of interests that combines agriculture, forestry, wildlife, water conservation, environmental quality, and a host of other resource management concerns. We have to find ways to integrate our efforts at the most local level--right out there on the land--if we are to make a real difference in the ways land and water resources are really managed. We have to not only have great ideas, but be able to get solid action.

The conservation districts of America are dedicated to this goal. They are equipped, both by state law and through 40 years of experience, to serve as a focal point for action. They are involved, both at the local level, and nationally through NACD, in an intensive search for more effective soil and water conservation programs. They can help bridge the gap between the agricultural community and the wildlife conservation community, and open the communications that will be so vital to the ultimate success of our efforts to retain wildlife habitat and values as we continue to use, develop, and manage the soil and water resources upon which our whole society ultimately depends.

We need to work together, as agriculturalists, conservationists, and wildlife specialists to define and implement an agricultural production policy and a natural resource conservation policy that work together and complement each other. Only with a stable, healthy agriculture can we both reduce the need for mitigation and, at the same time, be able to afford the kinds of mitigation that will be unavoidably needed.

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Mitigation - Issues for the 80's[1]

R. F. WALKER[2]

Abstract.--To assure audience of industry's serious interest in mitigating real wildlife habitat losses, while cautioning against the exploitation of genuine wildlife issues to stop projects for the sake of advancing other social and economic issues.

Albert Schweitzer, in dedicating Rachel Carson's Silent Spring, said, "Man has lost the capacity to foresee and to forestall. He will end by destroying earth." Dr. Schweitzer's sentiment seems very much in vogue today. One result of this could be a virtual halt in human progress.

One lesson of science seems to be that the more we learn, the more we find out how much there is yet to learn. So we feel we really know very little about a lot of things. Reinforced by various human actions, this enigma has inspired the notion: "If we cannot foresee the results of our actions, then we should not act." Projects are halted for "further study," but often such study uncovers more questions than answers.

Governor Dick Lamm, addressing the Conservation Foundation conference in May, said that he was not sure, when we write the history of these times 20 years from now with the advantage of hindsight, whether things would be much clearer. But he did feel this would be cause for inaction.

The controversy surrounding development in the Front Range in Colorado prompted Governor Lamm's suggestion that a coalition of people get together to try to come up with something different. He said, "We are going to need an armistice in the war between growth and its detractors. We must start anew and find common values that we can rally around. The polarization of the early 1970's will have to give way to a new era of cooperation in the 1980's."

Has mankind lost the capacity to foresee? I believe that we are now, more than ever, aware of the far-reaching consequences of our actions. Our vision has been extended in all directions. We quite properly pay attention to a small fish or flower or wonder if drilling in the Island Park Geothermal Area just might not upset Old Faithful, some 15 or 20 or more miles away. This Symposium is evidence that man has the capacity to foresee. No, we don't have perfect foresight, but our vision is much improved.

We have the capacity to foresee and we must exercise it. Which calls for an additiona capacity -- "the capacity to agree." To agree in a true spirit of cooperation. Unfortunately society has many conflicting needs, and each of these needs has particular and partisan propone Too often, "tunnel vision" serves to advance the needs of a particular person or group to the detriment of the general welfare.

Fortunately, our expanded capacity to foresee includes a growing realization that lack of foresight and tunnel vision have been responsible for torpedoing the efforts of individuals, companies and government agencies not to mention the common goals of society. Current legislative efforts seek to overcome poor planning and lack of cooperation by requir early planning and consultation. The National Environmental Policy Act, for example, recogniz the necessity of weighing environmental needs against social, economic and other requirements of both present and future generations.

The recently proposed rulemaking under the Fish and Wildlife Coordination Act seeks to further cooperation by allowing one lead agency to complete the Act's consultation and reportin phases when two or more agencies have jurisdiction over an action. This, according to the no of the proposed rulemaking, should eliminate th "two bites at the apple" problem. The proposal therefore, are in keeping with President Carter directive that federal agencies should coordina and simplify environmental review requirements.

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[1] Paper presented at the Mitigation Symposium, July 16-20, 1979, Colorado State University, Fort Collins, Colorado.

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However, when it comes to the attempts of electric utilities to build a power plant, or of any company or agency to undertake a major project, even "two bites at the apple" would be a dramatic and welcome improvement. Due to conflicting and overlapping regulations and the numerous opportunities for intervention in the attendant proceedings, it may take 14 years or longer in some areas of the country to build a major power plant. Rather than "two bites at the apple," it is more like falling into a stream teeming with toothy piranas, where barely the core of the project survives.

Electric utilities historically had been in the fore in the accuracy of their long-range planning. Now uncertain and changing regulatory requirements are eroding that ability.

Ironically, the trend toward opening official proceedings to public participation frequently acts contrary to the public interest.

Various individuals and groups, with single-issue constituencies, are able to intervene in their own behalf with no regard to the broader public interest. Thus, in the name of wildlife loss mitigation or environmental protection, can an individual use the Fish and Wildlife Coordination Act or the National Environmental Policy Act to advance a personal philosophy of "no-growth." As a result, legislation may be used to thwart its own goals as well as the broader goals of the public interest.

Unless a spirit of cooperation can be introduced, chaos will result. Either harmful actions will be taken or stalemate and inaction will result. The trend toward more and more litigation in our society is ominous. Also, calls for "further study" are used on one hand to halt both further development and on the other hand, in the meantime, to impose more regulations.

Those who call for "no-growth" as a policy personify what Harper's editor, Lewis Lapham, has called a "fear of the future." Such a fear, he observes, tends to "blow up the bridges over which the human family travels into time future." We cannot stand still and we cannot go back. We can minimize the impacts of our action, but "zero impact" is impossible. Life is change. And change is the life force of a progressive, productive society.

Overcoming the tendency toward confrontation rather than cooperation might appear an overwhelming task. This symposium, by way of example, covers just one area of social concern -- preventing or alleviating the unnecessary loss of wildlife habitat. Yet 125 papers, representing 125 separate viewpoints, will be presented in the course of this meeting. And pertaining to fish and wildlife regulation alone are more than 100 federal statutes and international treaties, not to mention state laws and regulations. Compounding the myriad concerns and regulations is the sobering fact that world population will expand from four billion today to six billion by the turn of the century. Our work is cut out for us.

The uphill task of working in a spirit of cooperation with an eye toward the broader public interest, is made more difficult by the frightening possibility that the citizens have lost control of government. Burgeoning regulation has become a form of "taxation without representation" with much of it beyond the control of elected officials. Commissioner Roberta Karmel of the Securities and Exchange Commission noted, "Congress . . . can remedy only the most flagrant regulatory mistakes. To a large extent, therefore, regulators must rely on their own devices in defining the public interest."

There is a tendency for special interests to prevail in what Harper's editor Lapham called the "retreat from democracy." Representation of the public interest must be kept in mind at all phases of the governing process. A spirit of cooperation is needed in the drafting of legislation and regulations, and in their subsequent administration and interpretation. There must be sufficient time left between all this legislation, regulation and litigation to actually get something done.

We must keep the broader public interest in mind when carrying out our affairs.

Further progress in fulfilling any of our particular interests will require that we try to understand the other interests involved. Ultimately, the world won't work for anyone unless it works for everyone.

By way of furthering the move toward cooperation, I would like to try to convey an understanding of some of the problems the electric utility industry faces in fulfilling its particular franchise. One important fact is that the totality of regulations, environmental and otherwise, has an impact greater than the sum of its parts. A multitude of regulations affect the siting, construction and operation of power plants and other facilities, as well as the choice and availability of fuels. Our rates, too, are regulated.

As a consequence of overlapping, conflicting and imprudent regulations, and just the sheer mass of regulations, significant delays are occurring in the planning and construction of needed power plants and other facilities. While this creates increasing headaches for utility planners and administrators, it also creates unnecessarily higher electric bills for consumers and the real threat of power shortages in the years ahead.

Delays in bringing new coal-fired and nuclear plants into operation, combined with restrictive regulations regarding the mining, transportation and use of coal, means we must use additional imported oil. According to a study made by the Edison Electric Institute, oil consumption will increase by 530 million barrels per year by 1990, due to the Environmental Protection Agency's new source performance standards.

President Carter last Sunday announced his administration's goal of reducing by 50% the consumption of fuel oil by power plants . . . within the next decade. It seems obvious that that goal can only be achieved by prudent relaxing of EPA standards.

From our perspective as suppliers of vitally needed energy to the economy, we clearly see the need for compromise and a national consensus to permit attainment of environmental, energy, economic and other important national objectives. Our industry recognizes that the tremendous importance of the need for energy does not mean that wildlife and other environmental impacts can be ignored in meeting that vital need. But progress on all fronts demands a balancing of competing interests and coordinating, simplifying and expediting regulatory processes.

Concerning wildlife management, the electric utilities have significant involvement in this area -- mostly in spite of pertinent legislation, rather than because of it, as described in the May issue of Audubon in the article "A New Hand in the Wildlife Business."

An industry survey made by the Edison Electric Institute found that 74 percent of the electric utilities have wildlife management programs. Also, 24 percent have set aside land for special purposes such as wildlife refuges and natural areas. In tomorrow's concurrent session on power plants, further results of this study will be presented in an overview of utility involvement with wildlife. Several panelists also will detail specific examples of utility mitigation efforts.

Public Service Company of Colorado is proud of its environmental programs and of our efforts to incorporate early planning and cooperation in our activities.

At the Company's Valmont steam-electric generating station near Boulder, for example, it was recognized in 1924, at the time the plant was built, that it need not be out of harmony with its natural surroundings.

The 860 acres comprising the plant site were set aside as a fish and wildlife preserve. The details were worked out with the Colorado State Game & Fish Department and Federal Fish and Wildlife Service. The 500 acres of lakes on the site abound with bass, crappie, bluegill carp and trout.

There is evidence of another unusual inhabitant of the lake, each fall, for a period of one week to 10 days. The creature is a smal jellyfish, about one-quarter to on-half inch in diameter. As you know, jellyfish are rather common in salt water, but they are rare in fresh water.

On their way South each fall large flocks of Canadian Geese stop off at Valmont for a few days. Ducks of just about every variety visit the lake from time to time. Birds of all types indigenous to this area travel, feed and nest freely on the preserve.

Among the recognition we have received for demonstrated environmental and wildlife concern is a citation from the National Audubon Society for involvement in a program to reduce eagle mortality rates from power line electrocutions. The success of this program was due largely to the spirit of cooperation among the several utilities, agencies and environmental groups involved.

Another example of efforts to protect wildlife is our plan to develop a reservoir, in connection with the Pawnee steam-electric generating plant in northeastern Colorado, which will include an island to serve as a second nesting colony for the White Pelican in Colorado. This colony will diversify the breeding population, and hopefully increase the population of this endangered species. Unfortunately, this reservoir has raised a question concerning whether it will reduce stream flow in the Platte River to the point that it will impact a Whooping Crane habitat several hundred miles downstream in Nebraska.

We have recently submitted documentation to the U.S. Fish and Wildlife Service which indicates that the reservoir will have no impact on the flow or width of the Platte River in central Nebraska where the whooping crane habitat exists.

We hope that this documentation will lead to an agreement between the Fish and Wildlife

Service, the Corps of Engineers and ourselves that construction of the reservoir can go forward without delay.

The alternative is a delay somewhat similar to Wyoming's Grayrocks Dam controversy. As you will recall, that project was well under way before a determination was made that the Platte River would become less desirable as a stopover habitat for approximately 75 migrating whooping cranes. This despite the fact that many people question whether there is conclusive proof of adverse impact.

Nevertheless, an out-of-court settlement of $7.5 million was required to prevent project delays that would jeopardize the in-service date of the Laramie River Power Station.

Cooperation is also needed relating to the problem of birds colliding with power lines.

There's no question that many birds are killed yearly by such collisions. There is doubt, however, that such losses significantly affect total bird populations. Preliminary studies into the problem seem to substantiate that.

The Bonnevile Power Administration, for instance, has early results from such a study on their system indicating that no significant mortality rate is occurring from bird collisions with lines even in areas of high bird populations.

Certainly at this point, there is no clear scientific evidence, either supporting the hypothesis that power lines significantly reduce bird populations, or opposing it.

In light of such lack of knowledge, we must ask ourselves if the public interest is served by delaying construction of a power line -- which may be badly needed by human populations -- on the possibility that construction of the line could adversely affect bird populations. If studies eventually indicate there is a major bird loss, cooperation by all parties will be needed to solve the problem.

A final Colorado example of successful mitigation, is that of the cooperative wildlife management project at the Ray D. Nixon coal-fired power plant south of Colorado Springs. Under an agreement between the Colorado Division of Wildlife and the Colorado Springs Department of Public Utilities, wildlife personnel initially will develop a management plan for a 1200-acre area with additional lands to follow. The project will serve as habitat for various birds and animals including raccoon, deer, antelope, pheasant and quail. The project would serve as a demonstration of the harmonious meeting of energy and environmental needs.

Early planning is the watchword of our comprehensive site selection process which enables full and early consideration of environmental impacts in the siting of power plants and transmission lines. Public Service Company of Colorado, in 1973, began a three-step procedure for the study, analysis and selection of prospective major power plant sites and high-voltage transmission corridors. The first step was basic environmental inventory of the entire state of Colorado. The purpose was to identify those areas of the state that would present significant environmental problems.

Step two of the process includes technical and economic feasibility studies of those areas remaining after eliminating areas that were environmentally ill-suited or unavailable for other reasons. The final step includes detailed engineering and environmental studies of any site or sites deemed suitable for final consideration.

The statewide environmental inventory performed by independent consultants considered the following criteria: air quality, terrain and geologic features, wildlife and fisheries, aesthetics and ecologic sensitivity. Areas of land unavailable for reasons of existing use or ownership were eliminated from consideration. Additionally, impacts on recreational and agricultural land use were considered.

The detailed site studies made by the Company in this process include an environmental resource inventory analysis of: air quality, vegetation, fisheries, aesthetics, critical ecology, historical and archaeological significance, and cultural and socioeconomic factors. Based on these studies an environmental impact analysis is completed.

A major objective of this site selection process, of course, is to build a power plant that meets the highest levels of efficiency at a reasonable cost. But, at the same time, land use consideration and environmental protection are given equal priority.

I am sure that utilities throughout the United States are involved in programs of a similar nature. I am also sure that they are faced with the same growing obstacles to this process, that I have mentioned. It is absolutely essential that avenues continue to be developed for resolving these conflicts in an atmosphere of true cooperation.

So where do we go from here? Unless we develop the mechanism for resolving the stalemates posed by confrontation, the only "winners" will be the proponents of "no-growth." It is not fair to the American public to use wildlife or similar issues to advance the economic and social causes of those who wish to stop growth.

If "no-growth" is a desirable policy, it should be advanced on its merits and not achieved de facto through the misuse of legitimate legislation, regulations and proceedings.

Perhaps an "environmental arbitration board" somewhat like the National Labor Relations Board could serve on a federal or state level to help resolve environment-energy conflicts. The National Coal Policy Project might offer a prototype for establishing mechanisms to achieve some sort of common ground. In this region, the Rocky Mountain Center on Environment (ROMCOE) serves as an excellent model.

We have the capacity to foresee. We have the capacity to agree. We must now commit ourselves to fulfilling those abilities. Regardless of the mechanisms, the key ingredient is a true spirit of cooperation.

Wildlife Mitigation and Energy Development: Balancing our Heritage and our Future[1]

Howard A. Slack[2]

I am pleased to have the opportunity to address this important symposium devoted to the critical and ever challenging problems inherent in the dual goals of utilization and protection of our national resources. Few things are more crucial today than a constructive examination of this process as it pertains to energy development and fish and wildlife resources.

The need for America to expand the development of its domestic energy potential is quite clear. Last month's OPEC move to raise oil prices another 16 percent should reinforce our resolve to become less dependent on the foreign oil cartel.

Almost 50 percent of the oil we use today comes from outside the United States and costs us billions of dollars a year, hundreds of thousands of lost jobs and a serious trade imbalance.

Ten years ago, we were importing 3.5 million barrels a day and were paying four billion dollars a year for it. Today we are importing about 9 million barrels a day and paying 70 billion dollars a year. In this 10-year period, the price of foreign oil has risen nearly 1,000 percent -- and where it will go from here is anyone's guess.

This country does run on energy. The need for us to increase all forms of domestic energy production is real. And the need for us to do so with as little disruption to the environment is just as real.

We in the petroleum industry recognize our obligations to our fellow creatures with whom we share living space on this earth, and we are making concerted efforts to retain a livable environment for them as well as for us. Our mitigation efforts extend from the Arctic Ocean to the waters of the Gulf of Mexico. They involve species ranging from sage grouse, dall sheep, and salmon to antelope, elk, and caribou. They extend from our western energy lands to the waterfowl, whooping cranes and fishery resources of the Gulf Coast. And, we are concerned as well, with maintaining suitable habitats for the unseen creatures of the soils and waters through whose activities the nutrients essential to life are cycled from the living to the dead and back -- to be reused by new life in never-ending cycles. We appreciate the intricacies of ecosystems and are as intrigued as John Muir years ago to find that everything seems to be hitched to everything else in the universe: humans to wildlife to plants to soils to bugs to birds -- to carbon atoms...

I have just moved from Anchorage to Los Angeles after nearly a decade in charge of ARCO's Alaska Office. I was there during the long years the unused pipe for the pipeline gathered rust in storage yards, and I remained to see the first tanker loaded with Prudhoe Bay oil move south from Valdez to the refineries in the Lower-48 states.

Today, that 1.5 million barrels a day of critically needed oil from Alaska's North Slope is saving this country from having to import that much more from foreign sources. And the money expended stays in the U.S.

I mention the pipeline here because it's a classic example of what industry can do to mitigate losses to fish and wildlife resources.

During the years of litigation that preceded the construction of the pipeline, the seven companies involved initiated one of the most comprehensive environmental research programs in the history of the Arctic. More than 100 different projects involving some 100 million dollars were completed. Some 70 stream surveys were conducted to determine the spawning periods for the resident fish species along the pipeline route.

The dall sheep was a subject of extensive investigations, as were the caribou. The entire route was mapped for raptor nests and grizzly bear denning areas. Extensive revegetation tests were conducted at Fairbanks as well as at Prudhoe Bay. Hot and cold pipeline studies were conducted in permafrost areas and a comprehensive marine biological research program was developed for Prince William Sound. I could go on and on. These programs, designed to minimize the impact of technological activities in a little-known, hostile environment, have added greatly to an understanding of the natural history of the Arctic. Many projects are continuing with the financial and logistic support of the petroleum industry.

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[1] Paper presented at The Mitigation Symposium, July 16-20, 1979, Colorado State University, Fort Collins, Colorado.

[2] Vice President, Atlantic Richfield Company, Los Angeles, California.

To abate development activities at Prudhoe Bay, and reduce impact, oil extraction operations were unitized and directional drilling mandated. Thus, only two of the seven companies involved actually conduct drilling and one drill site can drain up to 160 acres.

Operations were often restricted by our full-time wildlife biologist when he felt they might impact wildlife. This was especially true during the nesting season of the snow geese and the calving season of the caribou. Regional garbage pits were established to minimize the attraction of scavenger species. Gravel pits were used as a source for the base of tundra roads and drill pads rather than disturbing river bottoms.

A team of outside environmental authorities including representatives from the Sierra Club and the National Wildlife Federation was organized to oversee pipeline construction. Perhaps some of you served as advisors. The group periodically inspected the progress of the pipeline and reported their findings directly to the president of the Alyeska Pipeline Company.

The Alaska Pipeline project illustrates that it is possible to have major oil development and construction in an environmentally sensitive area without destroying it. Oil development and environmental integrity can be sustained, provided reasonable mitigative measures are exercised. How much easier (and cheaper!) our task would have been if both environmentalists and industrialists had realized this in 1969 and we had worked together on solving what really were our mutual problems.

I believe that true conservation is the wise use of natural resources in the broadest national interest. The Alaska Pipeline stands today as a superb example of what can be accomplished when science and industry work together.

I'd like to back up now for just a few minutes to the period following World War II, when the petroleum industry was just beginning to widen its exploration efforts and to employ new technology for entering the sea and the Arctic environment. In the late '40s, the first offshore oil development began in the Gulf of Mexico and in 1957 oil was discovered in the Kenai Peninsula of Alaska -- in the heart of a national moose range.

Here oil-environmental problems were resolved more than a decade before the National Environmental Protection Act became law.

The companies worked closely with the U.S. Fish and Wildlife Service and designed mitigation plans for the resident moose population. The program was also closely monitored by State Wildlife biologists. Today, that oil field is still producing and is a model of multiple-use management with minimum impact. And how did the moose population fare? Well, it's larger today than before the oil was discovered. As wildlife biologists, you are well aware that many species of mammals adapt to human beings and live in harmony with them...deer, coyotes.. you know the species better than I.

We are still working very closely with the Fish and Wildlife Service in developing mitigation guidelines for future oil and gas developments on refuge lands. We're also assisting their coastal ecosystem analysis team in tooling up for an extensive research effort on the impact of petroleum development on living marine resources.

Like the Kenai, offshore activities in Cook Inlet, in 1958, were developed in coordination with the state of Alaska and its officials and University Marine scientists. The Cook Inlet field has been producing for more than 20 years without serious impact to this beautiful area.

Moving south to the Lower-48 states, we know that energy development -- including the mining of coal, uranium, oil shale and tar sands -- impacts wildlife resources in many different ways.

The overall effect of most land-based energy activities are similar, however, regardless of site characteristics. All produce changes in both the plant and animal populations at a site. More often than not, the public feels these changes are deleterious to the environment, forgetting that change is the order of the universe, and that natural changes occur daily, albeit not usually on the scale of, nor with the speed of, those produced by humans, and that "impacts" can be good as well as bad. The degree of the impact, however, depends upon the resource to be extracted and the methods used. For example, a solution uranium mine will have a lesser impact on vegetation and soil removal than will a surface mine for coal or an open-pit oil shale operation. The chance of contamination of runoff or water supplies by toxic substances will normally be greater for oil shale, uranium, and eastern coal mines than for western coal operations.

But, in general, there are 10 different aspects to be assessed in evaluating the effects of energy development on land.

1. Airborne Materials

Dust problems around development operations are common and comprise one of the more conspicuous aesthetic impacts. Except for the immediate area, however, dust is normally of little consequence to wildlife.

2. Ground and Surface Water Quality and Quantity

All states with major energy resources now have stringent water pollution control laws. The Federal Surface Mining Control and Reclamation Act also brings nonpoint pollution sources under regulation for coal mining. The control of both point sources and nonpoint source discharges has greatly reduced energy mining impacts on surface water quality. Large scale surface mining often requires the rerouting of small streams. The effect of such rerouting depends on the quality of the new stream channel. Adoption of proper construction techniques and proper planning and reclamation can recreate the conditions necessary for rapid establishment of a healthy and useful aquatic community.

3. Soils

Ground manipulation during mining or construction sometimes provides a better soil for plant growth, particularly where soil structure has inhibited plant growth in the past or where fertilization improves the mineral levels needed by plants. Topsoil with its microbial populations and reservoirs of seeds is salvaged and usually spread on reclaimed areas without prolonged stockpiling with present mining procedures. Disturbance and reclamation of limited areas each year also allow prompt use of salvaged topsoil and permit natural invasion by adjacent microbial and other plant populations.

4. Topography

Changes in topography resulting from surface disturbance can play a major role in determining which wildlife species recolonize the area.

Natural topographic features such as caves, rough breaks, cliff faces, hummocks, hills, valleys, and canyons are extremely important to various kinds of wildlife, particularly during inclement weather or during the breeding or nesting season. Increased topographic variations, including highwalls, can be a positive byproduct of energy development.

5. Vegetation

Effects on wildlife due to impacts on vegetation are attributable to two main factors: (1) complete removal or destruction of vegetation; and (2) establishment of new vegetation types which differ from the original plant communities.

Post reclamation success depends upon diversity, the type of management involved, and the presence of newly created habitat features. Native vegetation of low forage value may be replaced by species with greater palatability or by those which provide shelter to animals.

6. Land Use Practices

Present reclamation laws stress: (1) returning the land to its highest previous economic use; (2) achieving high vegetative biomass soon after revegetation; (3) uniformity of topsoiling; (4) grading out arroyos and highwalls; (5) filling of ponds; and (6) agricultural land. All of these act to decrease potential habitat and community complexity. This need not be the case with proper planning. Revegetation is the least expensive part of reclamation, absorbing, at most, 15 percent of the total cost. A wide variety of practices, if permitted by law or exemption, can be applied singly or in combination to increase land form diversity and hence, plant community diversity on reclaimed land.

7. Solid Waste Pollutants

Disposal of waste materials seldom results in a significant wildlife problem as long as the effects of such disposal are limited to the development site and do not persist beyond the life of the activity.

8. Fires

Most energy operations are well equipped for fire prevention and control; thus, fire-related impact to wildlife are normally rare and accidental in nature.

9. Direct Effects on Wildlife

Energy development and related activities can have three types of direct effects on wildlife: (1) changes in animal density and species diversity; (2) changes in the behavioral patterns of wildlife species; and (3) changes in wildlife mortality.

General observations, in many cases, indicate habituation to the development process if actual physical harm is otherwise absent. Since hunting is usually prohibited around energy sites, the nearby surrounding undisturbed lands often become sanctuaries. Influxes of big game into such areas have been noted during hunting seasons.

And finally --

10. The Effects of Human Presence

The primary factors determining the type and magnitude of "people" impacts are employment levels and the corresponding population influx and the stability of the work force through time. The severity of impacts is directly proportional to the total number of imported or nonlocal employees, the size of the construction force, rates of increase or decline in employment levels, and the land use and recreation demands specific to the incomes, age patterns, and other characteristics of the new residents.

Many potential wildlife impacts relating to energy development exist -- from air, soil, and water pollution to land form, vegetation, and habitat changes. Through sound resource and technological planning, these can be minimized.

Energy development, although not affecting every state or locality equally, has and will continue to have regional effects on land uses. How the land is managed after development and the extent of public pressures on wildlife resources will be primary impacting agents. By taking an active, positive role in government and industry decision processes, wildlife managers can be effective by identifying lands suitable and unsuitable for development, by establishing protective stipulations and mitigation requirements, and by promoting preferred wildlife-related post-development land uses. These actions will minimize adverse impacts and maximize benefits to wildlife populations. As experts, your advice and experience are needed.

Mitigating energy impacts at sea is a business we have been working at for more than 30 years. Ocean energy development began in the Gulf of Mexico, an area that today boasts the greatest concentration of coastal and offshore oil industry activity in the world. About 21,000 wells now lie in the offshore regions of Louisiana and Texas, and some 2,000 offshore platforms have been erected. In addition, 5,000 miles of pipeline extend 70 miles into the Gulf in water depths greater than 300 feet; and over 5,000 miles of canal pipeline rights-of-way have been built in the coastal marshes. Last year, approximately 14 percent of domestic oil production and about 23 percent of domestic natural gas production came from offshore wells primarily in the Gulf of Mexico.

Modern offshore oil and gas operations are conducted in a tightly woven matrix with stringent environmental protection procedures. All aspects of marine drilling are under strict regulation by the U.S. Geological Survey. All debris and waste material from the offshore platforms is returned to shore for disposal. Each platform has its own sanitation plant and only edible garbage is permitted to be disposed of at sea.

In the last 10 years, virtually every major university and college along the Gulf Coast has undertaken some scientific investigation of the environmental impacts of offshore petroleum development. Most reveal a high level of compatibility, with occasional environmental benefits, such as increased productivity around platforms.

One study, done by the Gulf Universities Research Consortium between 1972 and 1974, concluded that Timbalier Bay -- a 10 by 40 square mile area about 50 miles southwest of New Orleans -- has not undergone significant ecological change as a result of petroleum operations. Timbalier Bay has been under continuous development for 25 years; it now contains 400 oil and natural gas producing wells. The concentrations of all compounds in any way related to drilling and production were found to be sufficiently low there to present no known persistent biological hazards. In fact, the various natural phenomena, such as seasonality, floods, upwellings, and turbid layers, were found to have much greater impact on the ecosystem than do petroleum activities.

During the recent decades of intensive offshore development, the commercial harvest of fish and shellfish resources from the Gulf's waters has consistently increased. The fishery has not suffered. (This increase is probably the result of increased fishing effort -- and not due to the presence of these oil operations.)

Grand Isle, just off the Louisiana Coast, is now internationally rated one of the 10 best sport fishing areas in the world. Fishermen come from all over to verify what may seem like tall tales about fishing and offshore platforms or "steel reefs" as they are often referred to.

In yet another area of concern, the petroleum industry has been active in the mitigation of oil spill accidents. Response has taken the form of pre-positioning oil spill cleanup equipment in areas of oil operations along coastal portions of the U.S. today, we have in place a nationwide program of oil spill response capability in the form of oil spill cooperatives. Some of these co-ops have done site specific spill response planning with the primary goal of minimizing the ecological impacts of spills. This approach involves identifying biologically sensitive areas and developing methods to protect such sites in the event of a spill. In addition, guidelines for low-impact cleanup are developed for all environments within the plan's jurisdiction. These cooperatives function similar to volunteer fire departments, but with a mission of containing and cleaning up spilled oil. Municipalities, State and Federal agencies, and public organizations participate as full partners in these cooperatives along with the oil companies in providing instant response to spills throughout our nation.

I have presented only a brief and unfortunately incomplete overview of the role industry can play in mitigating the impact of its operations on our land and oceans. We desire to learn more, to be more sensitive, to understand the need for an integrated approach, protecting and developing our natural resources. We know that we have been given temporary stewardship of the resources for which we are responsible, and it is our responsibility to view that stewardship not only as a duty for today, but as an obligation for tomorrow. To this end, we pledge to work with the scientific community, the government, and the public to see that our approach is balanced and does indeed preserve our heritage for generations yet to come.

Keynote:

The Need to Move from Mitigation to Multi-Objective Planning[1]

M. Rupert Cutler

Abstract.--In a holistic approach toward project planning, concern for the welfare of wildlife is an integral part of project design rather than a reason for mitigation. Many environmental and economic values can be balanced. Small watershed and other USDA-aided programs have been improved significantly to demonstrate full respect for wildlife habitat.

I admit to experiencing more than a little frustration as I thought about how to help keynote this unique conference. Why? Because for the 25 years since I earned my undergraduate degree in wildlife management I've fought for better mitigation, and I fully support this concern. Yet I do not believe that a Federal agency--or any other body--has to be in the business of mitigation. Let me explain.

Almost by definition, "mitigation" is:

- An afterthought.
- An add-on to the planning process--often an unwelcome one, in the views of the construction agency.
- Often, an attempt to compensate for a mistake. And,
- At least in part, a failure.

It doesn't have to be that way!

I hope that, at this conference, we can begin to move project planning in America toward a more complete--"holistic"--approach, in which mitigation for any lost resource is unnecessary, or at least the need is greatly reduced. Let us move quickly to the point where habitat needs and a concern for the welfare of fish and wildlife become integral parts of the earliest phases of planning, so that attention to these concerns becomes an integral part of project design from the outset. And that includes the design of all the new energy-production projects apparently soon to be begun.

Within such a framework, we would spend most of our time documenting values instead of losses, and allowing for resources instead of repairs.

The U. S. Department of Agriculture has accepted and initiated a positive leadership role in protecting the environment. I have made a personal commitment to help strengthen that role. We are improving our own ecological expertise, and we are involving more agencies and more citizens in the planning process, so that projects and programs are more sensitive from the start to environmental, as well as economic, issues and values.

Some USDA programs in the past have adversely affected habitat for fish and wildlife. Some have greatly improved habitat. My aim as assistant secretary has been to assure that, wherever possible, the result of our actions is on the plus side for fish and wildlife.

Like many of you, I have sought to instill in public programs' decision making the essence of a "Bill of Rights for Living Things."

We cannot approach this job with a blind obsession for wildlife habitat. Rather, we must see that our programs consider and balance many economic and environmental concerns or values, in an attempt to optimize them all.

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[1] Keynote address by Dr. M. Rupert Cutler, Assistant Secretary for Agriculture for Conservation, Research, and Education, at the Mitigation Symposium, Colorado State University, Fort Collins, Colo., July 17, 1979.

In the past, wildlife management objectives have been given a somewhat less than co-equal status with other objectives in many Federal programs. We have made significant gains in blending local citizens' goals with the national goals of the USDA agencies that assist them, but the needs of plant and animal communities need to be accorded more respect, too, to enhance the long-term quality of life of all concerned.

I am dissatisfied with the concept that mitigation is a process designed to make up, in one location, for harming the wildlife resource somewhere else. Mitigation means compromise, on our terms or yours or someone else's. It often has been used as a "Band-Aid approach"...and may result in a net loss of wildlife resource benefits to society, permitting some habitat to be permanently destroyed.

I will pound the table for mitigation. But what values do we mitigate...replace... protect? What constitutes "enough" habitat of the "right" quality? Only when we can answer these questions will we have "arrived" at a mature process.

Other values of a project cannot make up for wildlife losses that may result. We must replace "in kind," or in a similar location; that is the USDA's policy. The net loss of "living things" to society, even with the best mitigation we know how to provide, must be minimized.

We ought to internalize the intent to enhance wildlife habitat and related values. We should document and include such values, at all project stages from planning to final design. We must move promptly toward designing projects and programs that are truly environmentally sound.

We must replace bandages with bioengineering; heal rather than patch; incorporate ecological principles into designs; and thus help local people and their government meet all their aims, together.

It will require a multi-objective interdisciplinary-team approach to appropriately:

- Identify goals;
- Exchange experiences and test results;
- Monitor conditions and evaluate actions after construction; and
- Collect and interpret data about impacts and values in a way that aids, rather than harms, natural resources.

The USDA is unwaveringly committed to that kind of positive and productive planning process in the future. We want to do all we can to achieve that future as quickly as possible. We welcome your ideas, and suggestions.

I am optimistic about the future of the USDA's small watershed program. Perhaps because of President Carter's personal interest and initiative in the area of water resources, the watershed program and other project-type activities have received close scrutiny in the past 2-1/2 years. In 1977 the President ordered a review of almost 750 watershed projects already in the construction stage, to spot and correct any environmental, economic, or safety shortcomings. The following year, the Soil Conservation Service revised its National Environmental Policy Act regulations to sharpen and tighten that process. You've noticed it doesn't rely on "negative declarations" so often now!

By April of 1978, the Soil Conservation Service had worked cooperatively with the U.S. Fish and Wildlife Service to develop and publish a set of guidelines to minimize the adverse effects of stream channel modification. An interagency task force is now finishing a review of field use of these guidelines, and will recommend by September whether they should be converted to binding regulations. They may become binding "regs" once we're all satisfied that they're workable.

By July of 1978, the President's water policy directives and Executive Orders on wetland protection and floodplain management were out, and were having positive effects on water resource development activities, beginning with USDA help in revising the Water Resources Council's Principles and Standards for Planning Water and Related Land Resources and in preparing a set of evaluation procedures to help implement them.

New projects will comply with all of the new policies. Environmental quality will receive equal consideration with national economic development objectives. That's the thrust of the revised Principles and Standards.

We haven't stopped there, though. Some projects approved for construction as long as 10 to 15 years ago have been looked at again and revised where needed to eliminate environmentally unsound measures or to add measures to minimize adverse impacts.

Three weeks ago I travelled with SCS Administrator Mel Davis to Ohio to review progress being made to reshape the way the Soil Conservation Service proceeds with its small watershed projects. Major changes have been made--and mitigation appears to have become a household word there. The Little Auglaize River project was stopped during construction to develop an environmental impact statement on the work remaining. Major changes had been made in the proposed plans. Additional safeguards were added as the result of my visit. Especially disturbing to me was the dragline work under way without Federal assistance, which was referred to as "brush and dip out" or "petition ditches." This Department will not assist or be associated in any way with such crude flood control work, in which all of the standing vegetation is cut, and the bottom of the channel is "dipped out" and piled along the banks.

Critics of SCS projects often overlook the fact that, where SCS-planned and assisted projects subject to Federal environmental protection requirements are not constructed, private landowners have had their county authorities proceed with such crude practices. The Soil Conservation Service has worked hard to build in respect for habitat, through preserving the natural bends in the river, one-side construction, wildlife plantings, revegetation plantings, design for shade, protected ox-bows, and constructed fish pools.

Two days ago I travelled with SCS State Conservationist Bob Halstead to review work under way here in Colorado on the Home Supply and Boxelder Watershed projects. Water is precious here. All of it is allocated. The temptation is to convert the cottonwood- and willow-lined irrigation ditches to underground pipelines or concrete flumes. But today the SCS is saying to their local farmer-cooperators in 50:50 cost-shared projects, all right, we'll take out "your" 50 percent of this woody vegetation as we reshape the ditches from one side, but we'll leave "our" 50 percent of the trees standing if we can, for wildlife habitat, under the guidance of SCS State Wildlife Biologist Eldie Mustard.

I assure you that we in the USDA are making significant progress in meeting the spirit and intent of the President's water policy message, which called for more efforts in mitigation. For example:

As of July 1, more than 1,000 miles of planned channel modification work have been deleted from projects since our Carter Administration reviews began. Fifteen projects have been deauthorized completely, some because of environmental factors, others because the local sponsoring groups no longer could meet their responsibilities in the projects.

And we are taking other steps to emphasize the importance of land treatment and other nonstructural approaches in meeting water resources, fish and wildlife, and other environmental aims. One example is a new requirement that 50 percent of the upstream watershed land be adequately protected from soil erosion--adequately by modern standards--before dams and other Federally aided structural measures can be installed. We have implemented cost-sharing changes to give added incentive to installing land treatment, such as terraces, in watershed projects.

Real, long-lasting improvements in watershed projects and in other SCS assistance to land users and communities will come through closer coordination with a wide variety of publics and with local and State agencies from the beginning of conservation project-planning efforts. We already have good examples of cooperation:

--In a Mississippi watershed project, the SCS had the "final" plan signed and sealed. Yet our Assistant State Conservationist and the Fish and Wildlife Service area manager led a full field review of the watershed and alternate solutions to problems. With the sponsors, they agreed on a number of changes to reroute or eliminate some of the work and to preserve wet areas, as well as protect cropland. Then we went back through the plan and EIS approval process. The result is a much better project.

--In a Tennessee project, SCS worked with Fish and Wildlife Service and Wildlife Management Institute staff members to develop new clearing and snagging guidelines to minimize adverse impacts and to benefit wildlife. The work now is being done, and much more smoothly than could have been possible before. SCS has sent a copy of the guidelines to every one of its State offices for possible adoption, along with some other research results related to aquatic habitat, and it has initiated a "dragnet" for other useful ideas, practices, and specifications of potential value in environmental planning.

I can tell you it's a pleasure to be personally involved in helping the watershed program continue to evolve to meet America's changing needs, mainly by encouraging such outstanding SCS professionals as Joe Haas and Carl Thomas to do what comes naturally to them.

In working with individual land users on a variety of soil and water conservation actions, the SCS also has encouraged mitigation of adverse impacts on wildlife as well as helping with wildlife improvement for its own sake. That "encouragement" may be simply not providing assistance in some activities, such as draining of wetlands to convert them to other land uses. Or it may be more positive aid in including and providing for fish and wildlife resources in planning the total use and care of a farm or ranch. More incentives are needed, however; an individual landowner with a limited total amount of Federal cost-sharing is unlikely to spend much of it on fish and wildlife. The landowner has to earn a living producing food and fiber, and wildlife too often must take a back seat. Changes are needed in the whole cost-sharing mix so that environmental values--especially water quality-enhancement opportunities--have a better chance of being considered and provided for.

Fish and wildlife concerns are among seven primary areas being studied under the USDA's Forest and Rangeland Renewable Resources Planning Act and Soil and Water Resources Conservation Act. (It's much easier to say RPA and RCA.) The Forest Service has finished its first RPA assessment and program development steps. The documents that resulted are aiding the Administration and Congress in setting forest management priorities. Mitigation is an explicit part of several forest and rangeland program elements, and will be tied in even more closely in the next RPA round, with full public participation encouraged. With my encouragement and under the new Chief of the Forest Service, Max Peterson, Dale Jones and his large cadre of Forest Service biologists will be given more leverage in FS decisions.

We are about to adopt important new regulations to implement Section 6 of the National Forest Management Act of 1976. They will require the Forest Service to conduct interdisciplinary planning and pay closer attention to wildlife mitigation and habitat enhancement as it draws up comprehensive land and resource use plans for each national forest. A biologist will be on every national forest land use planning team to negotiate on behalf of Lynn Greenwalt's "comfort zone" for wildlife. Streamside zones will be given special protection, in those plans, as will endangered species habitat.

Under the Resources Conservation Act, with SCS in the lead, the USDA is working to complete its first effort to provide a comprehensive appraisal and program guidance in strengthening our Federal and cooperative soil and water conservation programs. In the RCA, too, we are asking for more help from more publics, and accepting them as standard "interested parties." Not only are mid-course corrections of past programs needed, but new programs must be designed to cope with tomorrow's intensive economic pressure on the land to produce food and fiber from fencerow to fencerow for an expanding, increasingly more affluent world population.

Almost 200,000 Americans have provided ideas through the RCA process thus far. They have indicated a strong concern for fish and wildlife habitat. We want the people who know about, or care about, wildlife to have an opportunity from the beginning to help plan USDA projects and programs.

Our concern that wildlife and other natural resources be fully considered in program delivery also can be expressed through the important Cooperative Extension efforts of the Land Grant Universities and the extension unit of USDA's Science and Education Administration (SEA). The Renewable Resources Extension Act of 1978 provides explicit new authority to strengthen our informal educational programs for forest and range landowners and for other citizens. We have established a natural resources program unit in SEA-Extension, headed by former Michigan DNR wildlife chief Merrill "Pete" Petoskey, to ramrod Federal administration of this act. In the States, more Extension specialists eventually will be able to provide assistance to private landowners and developers to protect fish and wildlife values on privately financed projects. Good wildlife extension programs already are in place in several states, but increased funding to support these efforts is anticipated, even within a tight USDA budget.

Based on research by SEA, universities and other agencies, natural resources extension programs can help people understand relationships among land, water, wildlife, and other resources. Americans then may treat the land better themselves, and be more likely to support others' efforts to treat the land better. There may be much less need for mitigation or litigation.

I am convinced that every agency can do a better job in fish and wildlife management if we coordinate our research, information and education, program and policy development, monitoring and evaluation efforts.

For example, the Soil Conservation Service and the Forest Service together have reviewed the operation and maintenance of watershed reservoirs on Forest Service land throughout nine regions, and are taking positive joint actions to resolve any problems, including unnecessary adverse impacts on fish and wildlife habitat.

The SCS and the Fish and Wildlife Service have worked together closely on the National Wetland Inventory study based in Florida. They are drawing up a revised classification system for wetlands based not only on meetings and reports but also on a number of valuable and eye-opening field reviews in wetlands. The system will be ready by October, and then field tested for both credibility of inventory data and local and State acceptance of the system. SCS and FWS are coordinating in several ways to strengthen their programs.

At a recent Cooperative Forest Research Advisory Committee meeting, the Bureau of Land Management representative suggested that USDA's Cooperative Research program as well as its agricultural and forest research programs could be more responsive to the needs of the Department of the Interior's land management agencies. We'll be glad to make whatever shifts may be called for, to help assemble a unified data base for all public lands and their interface with private lands. I'm pleased that working relationships among the agencies in several departments are excellent, as demonstrated at meetings such as that one.

Within the USDA we have several institutional mechanisms in place for better coordination on mitigation:

--The Office of Environmental Quality attached to my office has important responsibilities under the National Environmental Policy Act to be sure that USDA agencies have adequate NEPA regulations and implement them. That Office, under Barry Flamm's direction, has played a key role, particularly in helping the Forest Service and the Soil Conservation Service through the National Environmental Policy Act process on significant Federal activities and through monitoring their response to the intent of NEPA. Many other USDA agency programs also have a significant impact on fish and wildlife resources, either directly or indirectly, through technical assistance, cost-sharing, loan, or grant programs. We hope to increase the staff of the Office of Environmental Quality to permit it to assist more USDA agencies in meeting the new NEPA emphasis on integrating wildlife values before deciding to proceed with projects.

--Our USDA Land Use Committee which I chair also is aiding coordination on many environmental fronts. Land use priorities as an outgrowth of, or as an influence on, a series of individual land-use and management decisions really are the bottom line in wildlife mitigation and other values. The committee has close ties with the land-use policy initiatives not only of USDA, but also of the Council of Environmental Quality and the Environmental Protection Agency. Several task forces within the committee relate to wildlife mitigation and enhancement.

As chairman of the Federal Coordinating Council for Science, Engineering, and Technology's Committee on Food and Renewable Resources, I plan to use this body as a key focal point for coordinating research across the Federal Establishment on wildlife mitigation and related topics.

--The Water Resources Council has made important strides in stimulating implementation of several of President Carter's water resources initiatives: maintenance of instream flow, improvement of watershed projects, revision of the Principles and Standards. Because I serve on the Water Resources Council as Secretary Bergland's alternate, I have participated in those actions and have urged that the WRC Principles and Standards be published as rules to permit third-party enforcement and be given a closer mesh with the CEQ's NEPA guidelines.

With all these coordinating mechanisms, I'm sure we can continue to improve our strategies for mitigating fish and wildlife habitat losses.

Yet I hope we can go far beyond that. Fish and wildlife concerns must be incorporated into the earliest discussions about water and other construction projects. Our designs should be responsive to environmental needs, just as they are to economic and hydrologic needs. When they truly are, we won't be talking about mitigation of losses, but about better design features. Then your future conferences could be labeled symposia on resource values, rather than on mitigation of wildlife habitat losses.

Thank you for your invitation to participate in this truly exciting conference and for your kind attention.

Marine Habitat Protection: Tougher Fights Ahead[1]

James P. Walsh[2]

I welcome this opportunity to address you on the subject of protecting vital marine habitats for fish and other wildlife. We at the National Oceanic and Atmospheric Administration are concerned about marine habitats because of our responsibilities for management of marine fish of commercial and recreational importance, marine mammals and certain endangered species, such as whales and sea turtles, and because of our statutory missions to research and monitor the effects of pollution on the marine environment. In the case of fisheries, the value of habitat to our commercial and recreational fishing industries is obvious--65 percent of all domestic marine fishing value is derived from wetland dependent species. As a consequence, we have made habitat protection a matter of high priority with our agency.

As NOAA Administrator Dick Frank emphasized last fall at Congressional oversight hearings on the Fish and Wildlife Coordination Act, the "destruction and degradation of marine, estuarine, and anadromous fish habitats is now the most critical long-term fishery resource problem." Furthermore, we believe that the most significant cause of species decline and extinction in the future may well be the loss of critical habitat.

We are marshalling our research resources to understand better the importance of habitats and the threats to them with programs under title II of the Ocean Dumping Act and other statutes; we are improving our review and comment ability under the Fish and Wildlife Coordination Act (FWCA) and the National Environmental Policy Act (NEPA); and we are vigorously pressing our views on other Federal Agencies that make decisions about habitat protection. And we are striving to carry out President Carter's recent Executive Order directing extra efforts for the protection of wetlands.

Concomitantly, it is also clear that the job of protecting and conserving marine and estuarine habitat is going to get tougher. Conflicts between protection and development continue to multiply in our coastal zones, especially conflicts over the use of dwindling wetlands. Soon conflicts over vast areas -- such as over D-2 lands in Alaska -- will be things of the past. The conflicts of the future will be over hundreds, or even dozens, of acres of habitat area. As competition for scarce resources in our crowded coastal areas intensifies, the tradeoffs among land and water uses threaten to leave many legitimate uses out of the picture. Widespread distrust of government and its regulations, even the ones that have always been generally supported, further weakens our ability to mediate these conflicts in individual cases. And the sheer complexity of natural systems and our lack of knowledge about critical habitats contribute further to making the job even tougher than it has been in the past.

Today I would like to talk about how we in NOAA are attempting to carry out this difficult-- and ever more important -- responsibility to protect and conserve marine and estuarine habitats. In doing so, I will concentrate on three major areas of NOAA's activities: (1) habitat protection activities, led by the National Marine Fisheries Service; (2) coastal zone management programs, including estuarine and marine sanctuaries; and (3) our broader pollution research efforts.

PROTECTING MARINE HABITAT: COPING WITH THE SIZE OF THE JOB

We take a broad view of habitat protection. Estuaries and near-shore waters are critical to the life cycle of many marine species. Yet we must be concerned also with the fish on the continental shelves and in our 200 mile fishery conservation zone, including the five Great Lakes. For example, many types of fish eggs go through their vulnerable early life on the surface of coastal, offshore waters. For benthic organisms the sediments are vitally important. In short, whatever the critical habitat -- wetlands, open ocean, or seafloor -- NOAA seeks better understanding of thre role of the habitat in the fish or mammal life cycle, and then tries to take the necessary protective actions.

Much of our effort goes into reviewing Federal permits, environmental impact statements, projects, and other Federal actions (such as state coastal zone management plans) that would in some way affect habitat. The National Marine Fisheries Service is NOAA's principal respondent to announcements of pending Federal actions. As an example of our workload, in 1978 the NMFS Southeast Region (one of five regions nationwide) was asked to review 6,098 applications for various Federal permits to perform work in navigable waters, 58 environmental impact statements, 97 Federal water development project plans, 1,239 permit applications for discharge of various pollutants into U.S. waters under the Environmental Protection Agency's National Pollutant Discharge Elimination Program, and 19 draft coastal zone management plans.

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[1] Paper presented at the Mitigation Symposium, July 16-20, 1979, Colorado State University, Fort Collins, Colorado.

[2] Deputy Administrator, National Oceanic and Atmospheric Administration, Washington, D.C.

Unfortunately, there is a great danger of being spread too thin by trying to cover all the situations that may affect habitats. The result could be less than "A" quality work. Consequently, we must select those projects that merit close attention. The factors that we consider in making such a selection include the size of the project, the importance of the living marine resources that are involved, the potential for impact (especially impacts that may be irreversible), the ability of others to handle the situation, and the precedent-setting nature of the case.

For example, in 1978 we spent considerable effort in evaluating the risks to marine habitat associated with proposed oil refineries at Eastport, Maine, and Portsmouth, Virginia. We have pressed NOAA's opposition to these projects at the highest levels of the Environmental Protection Agency, the Corps of Engineers and the Department of the Army. NOAA also played an important role in the Chief of Engineers Interagency Task Force which was formed to evaluate U.S. East Coast refinery sites as possible alternatives to the proposed Eastport and Portsmouth sites and which identified numerous better sites than those proposed.

The National Marine Fisheries Service carries out its FWCA duties through our new Office of Habitat Protection which was established within NMFS last year to ensure that FWCA activities get prompt, high-level attention. This office has a nationwide staff of 81. In turn these individuals can draw upon the scientific expertise of 165 other fishery researchers involved in marine population and habitat studies. Additional expertise is also available in our Environmental Research Laboratories, the Sea Grant Program, and our new Office of Marine Pollution Assessment.

In light of tight ceilings on Federal budget expenditures and personnel, despite our best efforts we have been able to comment on only bout 15 percent of the significant projects affecting marine habitats around the country. However, we are seeking, through alternative approaches, to increase the amount and effectiveness of our work in protecting habitat. One approach is to contract with states and private entities for field investigations at proposed development sities. We have a pilot project in one region which we hope will allow us to review 90 percent of the significant permit applications. If successful, this approach may enable us to increase the impact, timliness, and effectiveness of our efforts to comment on a large portion of the signficant proposals to alter habitat.

The growing volume of demands on the marine and estuarine environment makes the successful adoption and implementation of strong coastal zone management programs especially critical. Such programs can provide the basis which allows state governments to avoid inimical development in fragile marine and estuarine habitats. Under the Coastal Zone Management Act and regulations, habitats of particular concern must be inventoried by the States and procedures developed for protecting or restoring their conservation and ecological value. Fourteen state programs have been approved, and six more are slated for approval in the next several months. These programs cover more than 75% of our nation's coast. As the basic state programs come into effect, NOAA is launching a number of related efforts to strengthen the protection given to coastal and marine habitats.

- States with approved coastal zone programs are being required to devote an increasing percentage of their Federal funding to improvements in their initial programs to assure attention to four major national interests, one of which is the protection of natural areas. As a result of this approach, for example, Oregon's approved coastal management program requires mitigation for the placement of fill in tidal and intertidal estuarine marsh areas, and the Oregon Legislature has recognized the value of this approach by adopting it as State law this month.

- Working with the President's Council on Environmental Quality, NOAA is developing map overlays that identify coastal areas that are environmentally critical (such as habitats) and least suitable as sites for energy facilities or other major developments. These overlays will display, on a common base map, information on important coastal biophysical processes, species, habitats, economic activities and commercially valuable resources, air and water quality, residential and urban development, recreation, and legal-jurisdictional data such as coastal zone management designations. Putting this information onto a single visual format will help simplify the job of decisionmakers in evaluating development sites.

- NOAA is utilizing special task forces to address major questions such as the B Sea Outer Continental Shelf oil lease sale. We have assigned lead responsibility for preparing NOAA comments on oil and gas leasing on the Outer Continental Shelf to our Office of Coastal Zone Management. In turn, this office creates agency-wide working groups to respond to OCS leasing proposals. This approach augments the more routine efforts of the National Marine Fisheries Service and other NOAA elements.

- NOAA is experimenting with an effort in Grays Harbor, Washington, in conjunction with the State of Washington Coastal Zone Management program, to channel and control development in advance rather than fight it once it has been proposed. The goal of this special State-Federal effort, which is still being developed, is a comprehensive plan that will set forth all land and water uses (protection, conservation, or development) for the 100 mile Grays Harbor estuary for the next several decades. We are watching this experiment closely to see if it will be a success or should be tried elsewhere.

These supplemental efforts reflect the enormous strain we are under as a result of the traditional permit-by-permit, case-by-case approach to habitat protection. Unless we develop a better way and a broader perspective for addressing habitat protection, losses may occur simply because we did not have enough people and resources to deal with the crush of individual permits that now must be reviewed.

CURRENT ISSUES IN NOAA PROGRAMS

NOAA has a broad range of legal authorities which are the basis of our on-going programs. I would like to briefly mention some issues relating to our programs and legal authorities.

Fish and Wildlife Coordination Act Activities

The Fish and Wildlife Coordination Act is the basis for many of our habitat protection efforts. It is a sound statute which is critical to the entire national programs. Just recently, NOAA and the Fish and Wildlife Service issued joint regulations improving our implementation of the Act. We have identified two other problems in FWCA implementation that NOAA can attempt to remedy administratively. These are in the areas of follow-up and public awareness.

First, let me discuss the follow-up issue. NOAA routinely recommends that mitigation and ehancement measures be incorporated into construction projects. However, these recommendations are not routinely implemented, and, if they would require a change in the project or an increase in cost, these mitigation measures are often strongly resisted. Few construction or regulatory agencies have formal policies, procedures, or regulations which require them to account for the recommendations made by fish and wildlife agencies. The recommendations do not have to be incorporated as permit stipulations and, as far as we can determine, regulatory agencies do not follow-up to see that FWCA recommendations actively result in the desired implementation of mitigation measures.

To get at this problem, NOAA plans a pilot follow-up project this year in the Northeast. Detailed project plans have not been completed, but we expect to determine whether our FWCA recommendations were made part of permit or project stipulations, whether they were actually carried out as recommended, and whether these recommendations did in fact mitigate damage to habitats. Furthermore, we expect such follow-up studies to improve future recommendations and to guide us in allocating our program resources to those activities that are most effective for protecting fish habitat.

The second problem is a lack of awareness by the public about FWCA actions we propose to take. During hearings on the proposed FWCA amendments last year, NOAA was asked if a system existed for making FWCA recommendations and supporting research results known to the public. We had to admit that there was none. The information, of course, is public and we usually have an extensive network of informal discussions and consultations with particular groups. But no formal mechanism exists for notifying the general public that we have a concern, have taken a position, or have recommended certain mitigating measures for a particular project. Yet there is no reason why we cannot do this. We are now attempting to be more diligent in notifying the public on the actions we have taken and the reasons for them. Adequate public interest and involvement will definitely increase the chances that our recommendations will be implemented.

The Estuarine and Marine Sanctuary Programs

Two other major national programs, which NOAA administers, can also benefit habitat protection goals. These programs allow coastal States or the Federal government to acquire and manage areas of ecological importance, including important habitats. Our first estuarine sanctuary in Coos Bay, Oregon, contains 4,000 acres in South Slough Bay. It provides the State with a natural field laboratory and protects an important estuary. Five estuarine sanctuaries have been established and we are working on the next two. Two marine sanctuaries are now in place and several others are under under active consideration.

In some cases, a sanctuary can accommodate other uses as long as they are consistent with the primary uses of the sanctuary. Such may be the case with the proposed Flower Garden Banks Sanctuary off the Louisiana-Texas coast where the proponents of the sanctuary would like to protect a unique coral population within an area undergoing oil and gas drilling operations. Multiple use is also an issue in the Georges Bank area. The Georges Bank, which is off the Massachusetts coast -- a 20,000 square mile area-- has been nominated by a group of environmentalists and commercial fishermen for protective status as a sanctuary. The area is important as a source of fish and a number of endangered species of whales migrate through these waters. This area is also believed to contain oil and gas reserves that are becoming increasingly vital. A lease sale of oil and gas tracts on Georges Bank is scheduled to be held this fall. We are now collecting data in order to make the decision on a possible sanctuary on Georges Bank.

NOAA's POLLUTION RESEARCH: OMINOUS RESULTS FOR HABITATS

I would like to conclude my discussion by summarizing some results of our pollution research. These conclusions evidence serious problems for the animals we are trying to protect. Pollutants are in additional, insidious threat to wildlife habitat.

Congress has directed NOAA to research the effects of pollution on the marine environment in several statutes, including title II of the Marine Protection, Research and Sanctuaries Act. We also have an important government-wide coordinating and research role under the National Ocean Pollution Research and Development and Monitoring Planning Act.

Some dramatic research results have come from NOAA's Tiburon, California, fisheries laboratory where Dr. Jeannette Whipple has conducted a pioneering series of in-depth studies on adult striped bass. Dr. Whipple's findings provide possibly the first documentation of long-term chronic effects of pollutants such as heavy metals, PCBs and other chlorinated hydrocarbons on mature fish. Dr. Whipple has concluded that the pollutants in the San Francisco Bay estuary are weakening the fish and making them more susceptible to parasites and disease. These results have spurred the California State Water Resources Control Board to schedule fact-finding hearings on the problem next month.

In another precedent-setting work, one of our geneticists, Dr. Arlene Longwell at the Milford, Connecticut, NMFS laboratory, has achieved what is believed to be the first measurement of sublethal pollutant effects on fish eggs in the field. Dr. Longwell's data indicate that spawned Atlantic mackerel eggs are being adversely impacted by hydrocarbon and heavy metal pollution in a portion of their major spawning grounds in the stressed New York Bight. Her work shows that these pollutants can inhibit normal growth and development of mackerel eggs.

In the heavily stressed New York Bight, much of the work at our Northeast Fishery Center has been useful in drawing cause and effect relationships between various pollutants and incidence of diseases in fish. For Example, research and monitoring activities have shown a high incidence of black gill and exoskeleton erosion in shrimp, crabs and lobsters in natural areas polluted by organic wastes, chemical contaminants, or copper. In the laboratory, similar species are being exposed to similarly contaminated sediments and the same disease syndrome is appearing, leading us to believe that these symptoms can be related to the degree of pollution.

At the Great Lakes Environmental Laboratory in Ann Arbor, Michigan, scientists working on the phosphorus problem have studied the mechanisms for recycling pollutants in the ecosystem. These scientists have learned that pollution recycling in the Great Lakes ecosystem is a very complex process and a full understanding of all physical chemical and biological components must be available before predictions as to the future of the ecosystem can be made. We have learned that it is not enough merely to stop putting certain pollutants into the environment and then expect the problems to go away. Interactions in the marine and Great Lakes ecosystems are extremely complex and will require our continued research in order to properly determine our future course in the area of habitat protection. As I said before, habitat protection is going to get tougher.

SUMMARY

The wildlife and fishery resources of this nation are the trust responsibility of State and Federal governments. Certain Federal statutes spell out the manner in which our trustee responsibility is carried out. Common property resources require our efforts to ensure their continued availability for posterity.

Yet our efforts to ensure that habitats are not irretrievably lost will become more arduous in the future because of complexity, competition for scare space in the coastal zone, pollution problems, and, unfortunately, a fair amount of public indifference and distrust of government intentions.

I hope all of you remain committed to the effort; we at NOAA are deeply so.

Why Mitigate[1]

Frank Gregg[2]

Guy Martin has asked me to comment on the mitigation question for both the Bureau of Land Management (BLM) and the Bureau of Reclamation. On the surface, at least, one could hardly pick two more different agencies. BLM's mission involves multiple use of Federal land resources; Reclamation's mission involves multiple purpose development of water resources. The actions of Reclamation are far greater in scale and more site specific in effect than those of BLM. BLM is long-term program oriented; Reclamation is project oriented. The dramatic changes heralded by a major Reclamation project far overshadow, for example, adjustments to grazing use over large areas of land made by BLM.

Closer inspection, however, is likely to show that the hundreds of individual BLM management actions--in grazing, mining, recreational development, and other uses--have as great, and perhaps greater, long-term effect on fish and wildlife than the more dramatic projects of Reclamation.

There are other areas in which the two agencies are more similar than they seem. Both BLM and Reclamation are caught squarely in the middle of the national political and social pressures for maintaining our existing standard of living by helping ensure the flow of commodity and energy products while providing adequate safeguards for our environment. . . and the critters that live in it.

Under the Federal Land Policy and Management Act, BLM is charged with the responsibility of managing the lands and resources on the public lands under the principles of multiple use and sustained yield. And, fish and wildlife are among the major uses specified.

Reclamation's charge is much more specific: developing water resources in the West for irrigation, municipal and industrial supplies, hydropower, flood control, and recreation while at the same time maintaining and enhancing fish and wildlife values.

The conflicts inherent in these mandates are at the heart of this meeting. . .how can BLM, Reclamation and others manage resources to produce commodities and provide consumer services in a way that will have the least possible adverse impact on the environment.

So how are we achieving this? Clearly, location of Reclamation and BLM within the Department of the Interior along with the Fish and Wildlife Service improves the likelihood of adequate responses to mitigation needs. How can we do the job better in the future? Let me describe efforts of the two agencies separately.

First, let's take a quick look at the recent history of BLM's and Reclamation's fish and wildlife management and mitigation efforts so that you'll have some feel for the scope of current programs.

Virtually all of BLM's management programs--livestock grazing, timber and minerals management, watershed protection and others--impact fish and wildlife habitat in some manner. During fiscal years 1978 and 1979 alone, we spent over $26 million for on-the-ground improvements and associated maintenance work in connection with these four programs, much of which had direct effects on fish and wildlife. We spent another $4 million through our wildlife program on wildlife habitat enhancement work on some 20 million acres of public land. These improvements and activities range from installation of such things as wildlife watering facilities and vegetative manipulation projects to development and implementation of habitat management plans on key areas.

We know that BLM's efforts to safeguard wildlife have not always been as strong as they are today, or will be in the future. This is due to a chronic fundamental problem of outdated policies and inadequate funds and manpower. While we have come a long way in recent years, especially since passage of the Sikes Act, we recognize that we still have a ways to go to obtain the level of wildlife enhancement on the public lands that we all would like to see. The Public Rangelands Improvement Act of 1978 gives us an added "boost" in achieving this.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Director, Bureau of Land Management, U.S. Department of Interior, Washington, D.C.

A number of other BLM actions and decisions affect fish and wildlife resources in less direct ways and cannot be expressed easily in dollar terms. Some examples include establishment of livestock grazing intensities and areas and seasons of use; establishment of streamside buffer zones and protection of key habitats in timber harvest and mining areas; and determination of areas suitable for surface mining. These actions are designed not so much to mitigate negative effects as they are to ensure enhancement of the fish and wildlife resource in the overall context of multiple-use management.

Reclamation on the other hand, fits much better into the classical mitigation mold because its mitigation efforts are tied directly to the effects of specific water projects. Reclamation's authority for wildlife mitigation has in recent years been included in the authorization for each project. Prior to project authorization, the mitigation proposals are developed under authority of the Fish and Wildlife Coordination Act, which involves three steps: (1) Fish and Wildlife Service recommends specific mitigation measures; (2) Reclamation analyzes the recommendations and makes a determination as to which recommendations will be included; and (3) the Department and OMB then reviews the proposal which may or may not be further modified by Congress. Throughout this process, questions arise as to "what is justifiable mitigation."

Since the Coordination Act does not place a responsibility upon construction agencies to perform a specific level of mitigation, there has always been a difference of opinion as to the adequacy of mitigation for Reclamation projects. Even where mitigation has been authorized, at times Reclamation has had difficulty in accomplishing the planned mitigation due to funding limitations or other unforeseen problems such as escalating land prices and changes in mitigation concepts during project construction.

An example of the Bureau's mitigation program is illustrated by the experience of their Upper Colorado Region based in Salt Lake City. Prior to the late 1930's, there was not much attention given to fish and wildlife resources in project development. With enactment of the Fish and Wildlife Coordination Act and subsequent amendments, some fish and wildlife mitigation measures began to be included in specific project authorizations. In 1956, the Colorado River Storage Project Act was passed. Section 8 of the Act provided for mitigation and improvement for fish and wildlife resources and the Region's mitigation efforts increased as a result. In that Region, prior to 1956, about 1/2 of one percent ($950,000) was specifically allocated to mitigation out of $181 million spent for construction of 14 projects. Since then 16 projects have been completed through 1977, and, of the $802 million spent, about 6% ($49 million) has been earmarked for mitigation.

Prior to 1956, the only substantial Reclamation mitigation feature in the Upper Colorado Region was a 1,800 acre waterfowl management area on the Weber Basin Project. Since the Colorado River Storage Project Act, however, some 25 major mitigation features have been included in projects being planned or constructed in that region. These involve: wildlife, waterfowl, and big game management areas which vary in size from 100 acres to 21,000 acres; fishing reservoirs and fishing access, and modification to penstock or river release outlets in dams for downstream temperature control.

What this suggests is that both BLM and Reclamation have a developing commitment to careful management of fish and wildlife and diligent efforts to mitigate losses associated with needed projects. How are these efforts carried out?

In BLM, there are three basic steps within the broadly-defined category of mitigation:

Step 1 is Better Land-Use Planning.

BLM has a comprehensive land-use planning system designed to tell us what resources we have, where they are located, and which use or combination of uses will provide the greatest net benefits to the public.

BLM's draft planning regulations, which are being developed to further implement FLPMA, are being revised as a result of public comment. The new process builds upon strengths of our existing planning system while beefing up public input. It also meshes the planning process with requirements of the National Environmental Policy Act.

Our planning process is designed to resolve conflicts. We simply cannot accommodate all users on a given tract of land. There have to be tradeoffs. Deciding which users can be accommodated in which combinations is the "bottom line."

Inevitably there is controversy. We will always have it. The pressures on agencies such as BLM and Reclamation will become more intense as the symptoms of shortages--such as gas lines--increase and commodity hunger becomes more acute.

All uses for a given area simply cannot be accommodated. Something must give, and sometimes it will be wildlife. When this occurs, we strive to ensure that crucial habitats are protected and development occurs on less crucial areas. Moreover, we try to build protective mechanisms into our planning so that those habitats which are seriously affected by development (surface mining, for example) can recover to a productive condition.

Step 2 is incorporation of protective provisions in leases, licenses, and permits.

We issue thousands of leases, licenses, and permits each year for rights-of-way, mining, timber harvesting, grazing, and many other purposes. Similarly, Reclamation negotiates water service contracts. Stipulations to safeguard the environment are a part of each "agreement."

The stipulations include whatever the authorizing officer (in BLM, this is usually the District Manager) thinks necessary to safeguard fish and wildlife resources. For example, permittee activities may be restricted during key periods of fish and wildlife activity such as breeding, nesting, spawning, lambing or calving and/or migration. Also, in construction of water retention structures, permittees would be required to provide for uninterrupted movement and safe passage of fish and to screen pump intakes to prevent harm to fish. The more important or crucial the wildlife habitat and values, the more extensive the stipulations.

This is a key element of mitigation and our success or failure in safeguarding fish and wildlife hinges on the appropriateness and quality of the stipulations AND on our effectiveness in ensuring that the terms and conditions of each stipulation are met.

Step 3 is an ecosystem approach to managing resources.

This means the development and implementation of government programs that are oriented toward on-the-ground management of all components of specific ecosystems. . .not the narrow functional categories that characterized many of our programs in the past.

As an initial effort in this regard, we are putting the final touches on a comprehensive rangeland management and improvement program. The program will address the full spectrum of resource values associated with rangeland vegetation, including, of course, fish and wildlife habitat and forage resources.

By focusing management on the resources of public land ecosystems, we hope to be able to balance competing uses in ways that reduce the necessity for mitigation exercises.

In the Bureau of Reclamation, mitigation efforts are designed to "make whole again" or "lessen the impacts" of those projects which, of necessity, negatively affect fish and wildlife habitat.

In project planning, Reclamation maintains active working relationships with the Fish and Wildlife Service and State wildlife agencies under provisions of the Fish and Wildlife Coordination Act to avoid or minimize impacts, develop adequate mitigation measures, and to see that these measures are implemented in project construction and operation.

Until recent years, most Reclamation project mitigation revolved around benefits obtained by managing existing habitat to increase its carrying capacity. Habitat adjacent to or near projects were put under intensive management to obtain maximum production of fish and wildlife for the purpose of lessening project impacts.

But with the recent development of the Fish and Wildlife Service's habitat evaluation policy and procedures, the situation is changing. These new procedures emphasize evaluation of losses primarily in terms of loss of habitat or wildlife productivity rather than in terms of user days or dollar values. Because of this, the result may be to increase the amount and costs of mitigation required in Reclamation projects so as to offset the loss in habitat productivity. This is proving to be the case in initial field experiments and trials on Reclamation projects.

Both agencies are fully committed to President Carter's Water Resources Policy Reform Message of June 6, 1978, which affects both Reclamation and BLM, as well as other Federal agencies. Basically, it:

- directs promulgation of regulations to implement requirements of the Fish and Wildlife Coordination Act to, among other things, provide equal consideration of wildlife with other features of water-related projects. (FWS and NMFS issued proposed rules on May 18, 1979.)

- directs funds for environmental mitigation be included in all construction appropriation requests for water projects on a concurrent and proportionate basis.

- recognizes that Federal or other water programs do not give adequate consideration to needed instream flow for fish, wildlife and other uses.

- directs a cooperative effort with the States to resolve problems related to instream flow.

- directs Federal agencies to improve, where possible, the operation and management of existing water projects and to provide for streamflow necessary to maintain instream needs below proposed dams or other facilities in the project planning stage.

Both agencies recognize the need to explore new approaches to mitigation. We are participating in interagency activities to develop followup policies and guidelines to further implement the President's directive. In the interim, we are also making a conscious effort to ensure that the spirit and intent of this directive is met in appropriate Reclamation and BLM program documents.

But beyond compliance with mandates, we need to find better ways of working cooperatively, particularly with State fish and game agencies.

Here's one possibility that might apply in BLM's program. BLM and an interested State wildlife agency could implement, on an experimental basis, the Public Land Management Area Stamp provisions of the Sikes Act. The funds generated by the sale of these stamps to hunters, fishermen, and trappers could be "plowed back" into habitat improvement-related work in Sikes Act management programs jointly developed by the State and BLM. It is conceivable, at least to me, that a portion of such funds could be used to encourage habitat management on private lands encompassed by development projects on public lands covered by a "Sikes Act" management plan. This would provide an incentive for doing more for wildlife, regardless of whether or not a water-related project occurred within the area, by helping enhance and stablize wildlife resources in the entire area. Any such efforts along this line would be in addition to, rather than a supplement for, Federal funds appropriated for mitigation work in project areas.

In conclusion, let me summarize:

- The shadow of conflict between commodity production and resource protection will continue to hover over us and perhaps become more severe.

- Development and environmental interests will squabble more vocally and more frequently as pressures mount to both use and preserve our resources.

- Both BLM and Reclamation have an active and dynamic role to mitigate loss or damage to fish and wildlife habitat.

- Our success, and that of others, is dependent upon a partnership with the States and a variety of other agencies and groups.

Despite dramatic differences in mandate and quite limited resources, both BLM and Reclamation are working hard to develop meaningful and effective programs for minimizing and mitigating the negative effects of management actions on fish and wildlife habitat.

Assuring Energy and Habitats for Tomorrow[1]

Ruth C. Clusen[2]

Abstract.--While the energy crisis can in part be dealt with through demand reduction, additional sources of liquid fuels are necessary. One such source is synthetic fuels produced from our abundant coal resources. Yet coal extraction and conversion can seriously harm fish and wildlife habitat. The Department of Energy is conducting research to assist it and the energy production industry in developing mitigation strategies.

As the Department of Energy's environmentalist, I am charged by law to be, in effect, the voice of the Department's environmental conscience. At the same time, I am part of the Department. So, I am committed to work for the goals of the Department and of the nation as outlined by the Administration and by the Congress. Those goals can be compressed into one: maintaining energy supplies to keep the country moving.

I am here, therefore, to explain that the Department of Energy wishes to do its job while doing its best to restore, to protect and to enhance environmental quality and to assure public health and safety. That is a paraphrase of the 1977 law that established the Department of Energy and my Office of Environment.

A lot has happened in the energy picture since I was invited in January to appear at this symposium---much of it in the last few weeks.

I won't recount in detail how our nation's energy crunch came about. The news media have been doing that all too well. We know that warnings of the crisis began in earnest in the last decade. We know that the oil embargo led to gas lines in 1973; that we returned to a period of blissful carelessness; that the formation of the Department of Energy was intended to improve the Federal government's ability to deal with the crisis. And, of course, there were the oil price increases of OPEC, the Iranian shortfall, more OPEC price hikes, more gas lines, and now, renewed and redoubled efforts to end the energy crisis.

The Administration consistently has placed conservation at the cornerstone of its program for meeting energy needs. And numerous documents--from government agencies and the private sector--have identified methods of reducing demand. These range from more energy efficient automobiles, appliances and industrial processes to improved methods for residential space heating and cooling.

And in his recent speech capping the Domestic Solar Policy Review, the President focused on new initiatives designed to greatly increase the nation's reliance on solar power in the coming decades. Several related measures are already underway as a result of the National Energy Act. The Department also is funding numerous demonstration projects--notably windmills and solar collection systems--that can make this limitless resource usable on a large scale.

But despite these efforts, additional resources are needed to fuel the nation's homes, businesses and vehicles.

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[1] Paper presented at the Mitigation Symposium on Assuring Energy and Habitats for Tomorrow, Fort Collins, Colorado, July 17, 1979.

[2] Ruth C. Clusen, Assistant Secretary for Environment, U.S. Department of Energy, Washington, D.C.

There are other sources of energy, but oil accounted for nearly half of our nation's energy consumption last year. And imported petroleum accounted for almost half of our total oil usage. And that was more oil -- domestic and imported -- than we used in 1973. Even though the Saudis have said they will increase their production by one million barrels a day for a short period, we are not out of the woods. Oil --- or substitutes for oil --- must be at the heart of our short-term solution.

Congress and the Administration are considering ways of encouraging the development and production of synthetic fuels. These liquid fuels and gases that can be produced from coal could prove very helpful as oil substitutes, providing that their environmental problems can be overcome. The United States has enormous coal reserves --- perhaps 200 years' worth. If coal remains relatively cheap to extract and world oil prices continue to rise, synthetic fuels made from coal could become competitive.

We have perhaps only 15 or 20 years to manage the transition from dependence upon traditional oil and gas supplies. And it will take at least seven to ten years to develop a synthetic fuel industry; this development will cost both government and the private sector plenty of money. The capital investment runs from $20,000 to $30,000 for each barrel per day capacity of a "synfuel" plant. But with imported oil going up, synthetic fuel plants built in the '80s should be more and more economically attractive in the '90s.

Because they can directly substitute for liquid fuels, synfuels are far more versatile than the direct use of coal. And they provide much greater insurance against world oil uncertainties. Direct use of coal, however, in industrial boilers and by utilities can help prevent absolute increases in oil imports. And a U.S. capability in synthetic fuel production can create a deterrent against future OPEC price increases above the level at which synfuels become competitive.

Up to this point I have tried to take the present energy panorama and focus on coal and the synthetic oil and gas that can be made from it. I have only touched on the renewable sources of energy --- solar, biomass, wind --- and have omitted other sources, including geothermal, nuclear fusion, and the conventional high- and low-head hydropower. I am not minimizing those other energy sources. My purpose has been to cram into a short time the background needed to understand how the Department of Energy and my own Office of Environment gets involved in the subject matter of this symposium.

Mining and the plants fueled by products from mines can contribute to the degradation of fish and wildlife habitat. Hydro-dams and their turbines can be particularly harmful to fish. Auto and truck exhausts can be of particular harm to forage and cover for wildlife. But mining and electric utility plants may very will be the major cause of habitat disruption, especially because of the need for water that accompanies both.

Coal, uranium and shale oil are all strip-mined in the West. In Montana, North and South Dakota, Wyoming, Utah, Arizona, New Mexico and right here in Colorado, coal is mined from the surface. Oil shale is mined or available for mining in Wyoming, Utah and in Colorado. Of the eight, only the three northern states are not major sources of surface-mined uranium.

Coal, of course, is also found in great quantities in other parts of the country. But the low-sulphur coal of the West is in great demand.

With almost any energy venture these days, the necessity for gaining governmental permits and licenses can delay facilities from getting on with production. But there are no time restraints on rehabilitating the torn and disfigured land after valuable materials have been mined. Yet, of course, the Surface Mining Control and Reclamation Act requires that.

My Office of Environment, through its Ecological Research Division, has demonstrated that a small moonscape tract in the mining area of Illinois can be restored to a grassy meadow. A small mountain of tailings from an underground coal mine was knocked down, spread out, replanted, and converted into a delightful spot for rabbits and other native fauna to thrive. It cost money -- some $15,000 an acre -- but the transformation took place in months after decades of ugliness.

How much easier -- and cheaper -- to rehabilitate strip-mine scars when detailed plans are made along with plans for exploiting the coal seams.

Environmental hazards associated with synfuels go beyond those of surface mining. It is known that exceedingly complex mixtures of organic and inorganic materials -- many potentially hazardous -- may result from coal conversion technologies. Predicting the environmental impacts from these technologies is complicated by the interactions that may occur between the chemical constituents before and after release into the surrounding environment. Furthermore, the design and location of the commercial synfuel plants and the particular pollution control methods used will influence significantly the occurence, size and reversibility of environmental impacts.

Air and water pollution, solid waste disposal, product spills and water consumption may have significant adverse effects on terrestrial and aquatic ecosystems. Historically most environmental research and assessment have been directed at assessing acute biological effects. Those effects are most likely to be detected near the point of discharge where concentrations are highest. As a general rule the specific chemicals that produce acute toxicity are the more highly soluble compounds that have low molecular weights and high rates of incorporation into living tissues.

On the other hand, the less soluble, high molecular weight pollutants are not readily incorporated into living tissue. But a few of those compounds tend to accumulate when assimilated in biological tissue, often in specific organs. Occasionally they accumulate through food chains. The insidious thing about such materials is that even when released at very low concentrations they may be biological time bombs. They have the potential for damage at later times and at far greater distances from the point of release than is the case for acutely toxic substances. Control technology for such materials may be extremely difficult to develop because minute quantities of these materials released over long periods can cause disproportionately large problems.

Thus greater emphasis should be placed on identifying chronic effects associated with source materials from coal conversion or synfuel technologies. Much more research must be done on those pollutants. And a major goal of the Department's coal conversion program is to develop liquefaction and gasification processes that are not only economically sound but also environmentally acceptable.

Chemical and toxicological properties of the pollutants must be more clearly learned. Predictive models must be developed. Additional research is needed on transport of pollutants. Major sinks and critical pathways must be identified. The effects of pollutants on man, fish, wildlife and other ecosystems must be learned.

Without going into detail, here are some of the studies that have been done through my office:

o Evaluations of the effect of air quality on crop growth and yields have been done to provide preliminary testing techniques.

o Young rainbow trout were exposed to sub-lethal concentrations of a chemical that influences predator-prey relationships; control trout were exposed only to river water, then both groups were presented to large predatory fish.

o Effluents from solvent refined coal and hydrocarbonization facilities were used in tests that showed varied effects on rainbow trout, the main test animal. Depending upon various dilutions, trout died, showed a narcotic effect, or survived.

o Relative toxicity, it was found, is influenced by plant operations that modify the chemistry of the effluent by the type of coal and by other factors.

This is by no means an exhaustive listing of the kinds of research being done, but rather a sampler.

Most of the ecological research funded by the Office of Environment follows the pattern of finding out how an animal or plant develops and lives in nature. Then ways can be devised for -- at best -- preventing disruption of the species or -- almost as good -- encouraging its return.

Not all such work is done in National Environmental Research Parks, but these parks are good examples of the method. The parks are outdoor laboratories for achieving the goals I mentioned at the start of my talk --- protecting and enhancing environmental quality. There are four National Environmental Research Parks, established by DOE and its predecessor, ERDA, since 1974. The first is at Savannah River Plant in South Carolina. The others are at the sites of the Idaho National Engineering Laboratory, the Los Alamos Scientific Laboratory in New Mexico and the Hanford Engineering Development Laboratory in Washington State. Some may find it ironic that all of those environmental parks are connected with nuclear research and manufacturing installations. Another park is being considered for Oak Ridge National Laboratory, also a part of the same nuclear family.

In addition, the Environmental Sciences Laboratory of Oak Ridge and the Savannah River Ecological Laboratory, both built by DOE, were dedicated this year. Scientists at each are working, not on new nuclear weapons, but on ways to keep our self-sustaining, self-regulating ecological systems functioning within the biosphere. Related work is done elsewhere under Departmental auspicies --- at Argonne and other national laboratories.

The Department is carrying out a series of studies on lands under its stewardship to identify all threatened and endangered plant and animal species. The research includes evaluations of their short- and long-term health, and the conditions of their habitat.

Some of these studies exceed the requirements of the endangered species law because they are aimed at finding out whether those species could be introduced successfully within DOE protected areas. We believe that if we manage our lands to protect these threatened and endangered species, we will be providing at least reasonable protection to the ecological aspects of the site. Besides, these species may develop into extra sensitive, early warning "devices" for a region.

Here are a few quick examples of the kind of work being done.

Several mountain lions and black bears are being tracked by radio on the Oak Ridge reservation. Scientists had thought those species were no longer surviving in the area. When radiotelementry supplies the home range of these animals, we can start evaluating requirements critical to their protection.

A species of dwarf oak recently has been found that was last reported in East Tennessee nearly 200 years ago. The plants associated with this oak represent a relic plant community. Therefore all must be protected to protect this one species.

At the Savannah River Plant, extensive studies of the red-cockaded woodpecker and the alligator have progressed to the point that we are no longer concerned about their survival. We are now looking at what basic biological secrets might be uncovered that might have application elsewhere. The alligators, incidentally, live in waters heated by discharges from nuclear reactors.

At the Hanford environmental park a band of elk has been established for the first time in a treeless interior region of the State of Washington. An article in a recent issue of Science magazine documented the case. The protective isolation and cessation of livestock grazing in the buffer zone around the nuclear facilities are credited with the achievement.

Two species of dwarf plants have been found on several rocky ridges and crests in that area -- members of the sunflower and of the buckwheat families. The protection of the dwarf sunflower has developed a finding that seems contrary to the Endangered Species Protection Act, and one we are repeatedly encountering. Many of these endangered species seem to be pioneer species. They occur only during early stages of secondary successions and are gradually crowded out if the plant community is protected and not subjected to fire or some mechanical disturbance. An occasional plowing or its equivalent is needed to sustain the endangered species.

Also in the same park scientists have developed a technique of using rejecta cast from the nests of the Great Blue Herons as an indicator of food chain contamination.

At the Nevada Test Site some 20 endangered plants have been identified. To be absolutely sure of identification, a Russian thistle was sent to its monographer in Russia for validation. Because these species are mapped, a small building was moved on skids --- around the endangered plants.

On DOE lands we have examples of nearly every energy activity or those associated with them, such as power line corridors. We study them to learn their effects on wildlife habitat.

All of this research provides background that my NEPA (National Environmental Policy Act) Affairs Division can use in working with the Department's technology offices, which prepare DOE's Environmental Impact Statements. The NEPA staff tries to assure that these documents include descriptions of appropriate mitigation measures. Especial attention now is being given to develop methods to assure that mitigation strategies will in fact be implemented when facilities are built or sites developed.

I am proud of the scientists working for and with the Department of Energy and its Office of Environment. They are by no means all nuclear and high energy physicists. Biologists, chemists, physicians, ecologists, and others are on the team. There also are economists and other social scientists. They and we are concerned about more than just the health and safety of man. We are concerned about plants and animals, and all aspects of the world around us.

We have to be, if our energy problems are to be solved --- solved in an environmentally acceptable way.

Mitigation of Transportation Impacts[1]

Martin Convisser[2]

It has long been the policy of the Department of Transportation to seek to avoid adverse impacts on the environment, including specifically impacts on fish and wildlife, and -- where impacts cannot be avoided -- to make every reasonable effort to mitigate these impacts. To implement this policy successfully, the Department needs the assistance of fish and wildlife agencies and professionals, from the very earliest stages of transportation project planning.

INTRODUCTION

I am delighted to be here at this Mitigation Symposium to discuss the Department of Transportation's policies and actions regarding the avoidance and mitigation of adverse environmental impacts, particularly impacts on fish and wildlife.

The Department includes several major operating administrations which administer key transportation programs, many of which have the potential for significantly affecting the environment, including specifically fish and wildlife. Of particular relevance are the federal-aid highway program, administered by the Federal Highway Administration (FHWA); the airport development assistance program, administered by the Federal Aviation Administration (FAA); and the marine environmental protection program and the bridge permit program, both administered by the United States Coast Guard.

ENVIRONMENTAL POLICIES AND PROCEDURES

It has long been the policy of the Department of Transportation (DOT) to seek to avoid adverse impacts on the environment and, where adverse impacts cannot be avoided, to make every reasonable effort to mitigate these impacts.

A major tool of DOT environmental policy is, of course, the National Environmental Policy Act (NEPA). The Department is one of the larger producers of environmental impact statements (EIS) under NEPA. The Secretary of Transportation's stated policy is that the Department will not only comply scrupulously with the procedural requirements of NEPA, but will utilize the EIS process as a substantive vehicle for identifying and resolving environmental issues and achieving environmentally satisfactory results in transportation decisions.

We try to utilize the EIS process, to use Secretary Adams' words, as a "one stop process" for complying with all of the relevant environmental requirements. These include the requirements of the Fish and Wildlife Coordination Act, the Endangered Species Act, the Coastal Zone Management Act, the executive orders on wetland protection and floodplain management, and others.

In addition to the requirements of NEPA and other statutes which also apply to other federal agencies, DOT has an additional requirement in its own enabling statute, the DOT Act of 1966. Specifically, section 4(f) of that Act states that the Department cannot approve any project which utilizes certain categories of protected lands, including wildlife and waterfowl refuges, unless there is "no prudent and feasible alternative" and--if there is no such alternative--that all possible planning has been done to minimize harm to the protected lands. As you will note, this statutory provision was enacted four years prior to NEPA and explicitly includes a mitigation component--"all possible planning to minimize harm." Thus, by specific statutory mandate, DOT has been in the mitigation business for over a decade.

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[1] Paper presented at The Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

[2] Director, Office of Environment and Safety, U.S. Department of Transportation (Washington, D.C.). The author is indebted to Camille Cleveland, of the same office, for her assistance in the preparation of this paper.

POLICY IMPLEMENTATION

Avoidance

Our first objective in implementing the above broad policies is to avoid environmental damage, where that is reasonably possible. In the case of lands specifically protected by section 4(f) of the DOT Act, we must avoid the lands unless there is "no prudent and feasible alternative." Some examples of avoidance follow.

"Everglades Jetport"

During the 1960's, the Dade County Port Authority began development of an airport just north of Everglades National Park. The airport was intended to be a major future commercial jetport for the south Florida region. However, there was considerable concern about the possible effect of a major airport just north of the Everglades on the quantity and quality of the water flow into the Everglades--and the resulting effect on the fish and wildlife of the Everglades. DOT, working closely with the Department of the Interior, therefore negotiated an agreement with the State of Florida and with Dade County to assure that the already partially constructed airport would not be utilized as a commercial jetport. In addition, it was agreed that there would be a program to observe the effect on the Everglades of the limited operations that were permitted at the airport. Almost a decade after this agreement was reached, monitoring and checking have indicated no adverse effects on the water quality or quantity in the Everglades.

Interstate 10, Louisiana

A major proposed portion of Interstate 10 in Louisiana was deleted from the Interstate system because it had been planned to traverse important wetlands. It was concluded that the adverse effect on the wetlands and their fish and wildlife resources would have been too adverse to permit the project to proceed.

Goleta Slough

The Coast Guard did not issue a permit for construction of a bridge across the Goleta Slough, a wildlife refuge, again because of the adverse impacts which it was felt the bridge would have had on the Slough and its resources.

Mitigation

In many cases, it will not be possible totally to avoid alternatives which may have impacts on fish and wildlife. In those cases, every effort is made to mitigate any possible adverse impacts.

Wetlands

Because of the importance of wetlands as wildlife resources as well as their other qualities, every effort is made to minimize impacts on wetlands. If a highway must be built through wetlands, we try to build it on structure rather than fill. For example, in the recent Route 50 project in Dorchester County, Maryland, the project would affect the tidal marsh adjacent to the Nanticoke River. The highway will include a bridge which will avoid the filling of 18 acres of wetlands, and will allow free movement of the tidal water through the marsh.

If we cannot avoid taking wetlands, we seek to compensate by creating new wetlands. For example, the Arundel Expressway, also in Maryland, will require taking 2.4 acres of wetlands in the vicinity of Marley Creek. The possibility of placing the facility on structure, in order to avoid the wetland taking, was found to be impractical. Therefore, new wetlands of equivalent size will be created in an existing open creek area, by the construction of a sandbag levee. In addition, part of the wetlands disturbed by the construction will be reconstructed.

In the case of Interstate 205 in Portland, Oregon, 1.1 acres of wetland adjacent to the Columbia River are being taken. Construction of a dam in an nearby Game Management Area, to enhance the area as a waterfowl habitat, is proposed as a mitigation measure.

Hydraulic Flow

Related to the above wetlands considerations, the assurance of continued important hydraulic flows should be a major consideration. For example, an existing highway across the waist of south Florida is being upgraded into a major interstate facility. As part of the construction, there will be the extensive addition of culverts which will result in an improved hydraulic flow under the facility, compared to the existing situation. This is an example of a situation we like to achieve wherever possible within our existing authorities--improving both transportation service and environmental quality at the same time.

River Channels

To the maximum extent possible, where a river or stream channel is affected, we try to reconstruct the channel with similar characteristics to the original channel. I-70 at Vail Pass is an excellent example. The reconstruction resulted in an increase in the number of pools, facilitating increased fish spawning and insect breeding which, in turn, will improve the trout habitat. A trip to Vail Pass is planned later this week, and I urge you to participate to see how careful attention to mitigation of environmental impacts can be applied.

Erosion Control

Erosion control is, of course, a standard measure in transportation projects. Both the Federal Highway Administration and the Federal Aviation Administration have established procedures for erosion control. In the case of I-93 in Franconia Notch, New Hampshire, for example, the plans for the highway include requirements for seeding, mulching and use of haybales to limit erosion; minimizing work in wet weather; the minimal use of heavy equipment for bridge or channel work; and explicit limits on the extent of exposed areas and the duration of time they will be exposed.

Timing of Construction

Increasingly, we are trying to time construction to minimize effects on the breeding, nesting or spawning seasons. In the case of I-205 in Portland, no excavation will occur from March to May in order to avoid interference with the downstream passage of fish.

Habitat Preservation and Creation

Airport sites and highway rights-of-way often provide habitat for wildlife. Careful planning of landscaping in these areas can provide food and cover for birds and small mammals. Even such matters as controlling mowing operations can provide increased habitat. A study in South Dakota demonstrated that restricted mowing of highway rights-of-way during the waterfowl nesting season enhanced the right-of-way for waterfowl habitat and increased populations.

The existing Miami Airport is an important habitat for the Burrowing Owl and the Blacktailed Jackrabbit. In fact, the airport has been designated, by agreement with the Dade County Audubon Society, as a Burrowing Owl Preserve.

One of the more complex habitat activities in which the Department has been involved relates to an endangered species, the Hawaiian Stilt. Construction of a new runway for the Honolulu International Airport, on coral mud flats in Keehi Lagoon, destroyed the habitat of the Stilt. Prior to this construction, therefore, a new wildlife reserve was set aside at the Naval station at Pearl Harbor, and a new island created within the reserve. The Stilt population was relocated to this new location prior to runway construction, to assure the continued viability of the Stilt population.

Wildlife Movement

Considerable effort has gone into research on methods of permitting wildlife movement under or across highways, to minimize the barrier effect of highways. In the case of I-93 in Franconia Notch, all bridges over streams will be constructed with terrain suitable for movement of animals along the stream.

Marine Environment

The Coast Guard has a major role in protecting the marine environment with its important fish resources. The Coast Guard's many activities in this category include pollution patrols to assure compliance with discharge regulations, surveillance of ocean dumping, and response to discharges of oil or hazardous materials in order to minimize damage and to remove the pollutants from the environment.

RESEARCH AND INFORMATION

The Department has issued extensive guidelines for the information of the transportation community and others in planning, developing and constructing transportation facilities, to avoid or minimize the impacts of those facilities on the environment. Among these documents are two that have been prepared directly by my office. One is entitled "Environmental Assessment Notebook Series: Highways." This extensive document provides useful guidance on mitigation in a variety of environmental impact areas, including specifically wildlife and waterfowl. The second document is similar, entitled "Environmental Assessment Notebook Series: Airports."

The Federal Highway Administration has undertaken or supported extensive research in this field. You will be hearing a great deal more about that in the transportation workshop session later this week. However, I would like to highlight, in particular, two excellent documents which are among the fruits of that effort: "Highway-Wildlife Relationships" and "Highways and Ecology: Impact Assessment and Mitigation."

CONCLUSIONS

The Department of Transportation can accomplish its goal of helping to protect and enhance fish and wildlife resources in transportation projects only with the help of professionals in the field of fish and wildlife. We need the early assistance and advice of fish and wildlife agencies at the state and federal level. I emphasize the word "early" because it is far easier to take account of fish and wildlife resources, and to avoid or mitigate impacts on them, if we are made aware of the resources and the needs at the earliest stages of project planning. Once project planning has gone beyond the preliminary stages, making adjustments becomes increasingly costly and difficult. The delays, costs and controversy which result in these circumstances do not benefit the resources we are all trying to protect, nor do they benefit the programs which the construction agencies are required to implement.

Only through a concerted effort to work together in a continuing, cooperative fashion, each agency seeking to understand the needs and viewpoints of the other, can we achieve mutually acceptable results. We solicit your assistance in this effort.

Corps of Engineers Mitigation Policy[1]

Brigadier General Hugh G. Robinson[2] U.S. Army

A discussion of fish and wildlife mitigation measures recommended by the Corps of Engineers for inclusion in project plans. These measures are developed in cooperation with the Fish & Wildlife Service under the President's Water Policy.

> Society can only pursue its normal
> course by means of a certain
> progression of changes.
> John, Viscount Morley

Two centuries ago, our country possessed a vast, undeveloped resource base. This seemingly inexhaustible base set the mood for the succession of development-oriented legislation passed by Congress--the River and Harbor Act and Flood Control Acts, the Federal Water Power Act, and the Reclamation Act, to name a few. Progress was the national priority. Fittingly, the Corps of Engineers Program stood for economic development.

It soon became apparent that undeveloped open space and prime wildlife habitat were not inexhaustible. Legislation began to reflect the national need to conserve, preserve and enhance what remained of our rich and diverse natural resources. By the time of the passage of the wide-reaching National Environmental Policy Act (NEPA) in 1969, the Corps had fully embraced the spirit of the environmental movement, resulting in major programmatic changes.

As our resources have yielded to development, our concern for their integrity has intensified. In his Water Policy Message of June 6, 1978, and his directives of July 12 of that year, President Carter reaffirmed our national concern. One of the water policy directives resulted in the publication of regulations to establish uniform procedures for Federal agency compliance with the Fish and Wildlife Coordination Act (FWCA). As we continue to discuss the evolution of these regulations, the impact on our program cannot be ignored.

* * * * *

Our Program.

The Corps develops fish and wildlife features for inclusion in project plans based on the recommendations of the Fish and Wildlife Service (FWS) and the involved state fish and wildlife agency. As a construction agency we are required to include in our report for authorization "... such justifiable means and measures for wildlife purposes as the reporting agency finds should be adopted to obtain maximum overall project benefits..." The legislation did not make it mandatory to include all recommendations of the Secretary of Interior or the Secretary of Commerce--only those justified measures that will optimize project benefits overall. This is the most difficult feature of the FWCA. We cannot in all cases justifiably mitigate for all damage to gain the economic benefits of water resource projects. Change--progress--inherently demands some trade-offs.

If all damages are not necessarily to be mitigated, how does the Corps determine which can be justifiably mitigated?

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Deputy Director of Civil Works, Office of the Chief of Engineers, U.S. Army, Washington, D.C.

One weakness of past Federal mitigation efforts was their almost total emphasis on game species, those that are harvested for sport or food value, as worthy of mitigation. Over the years, there has been a growing recognition that our fish and wildlife resources are valuable for reasons which cannot easily be quantified in dollars and cents. To achieve a balanced mitigation effort, non-game species should also receive attention. Activities such as bird watching and photography and the non-game species of wildlife they revolve around may demand specific habitat requirements not covered by traditional analysis.

Under the proposed regulations covering implementation of the FWCA, primary reliance will be placed on measuring losses and compensating for them on habitat-based evaluation methods. One approach to quantifying fish and wildlife values on a habitat basis is the Habitat Evaluation Procedures (HEP) now being developed by FWS. These procedures offer promise as a method of quantifying wildlife productivity values and determining not only project-induced losses but also positive contributions. The Corps has not accepted HEP in its current state of development as the only analytical method, but we believe that HEP can, with further refinement and improvement, be developed into an analytical and evaluation method considerably better than procedures in use today. We will continue to integrate these analyses, as appropriate, with the more familiar analyses such as key-species and user-day methods. We are working with and will continue to cooperate with FWS in testing and evaluating HEP. Experienced Corps planners are working at Fort Collins with FWS to help refine application of the methodology but little in developing the procedures.

Habitat productivity, as emphasized by HEP, is an extremely important aspect of measuring project impact but not the only one. Many values of fish and wildlife resources must be considered: recreation in the forms of hunting, fishing, photography, bird watching and other forms of nature study; commercial use, such as fisheries which provide food, employment, animal feed and special-purpose materials in industry and the arts; the relative scarcity of a species or habitat on a regional and national level; and the integrity and interdependence of significant ecological resources.

The value of these resources must be weighed against the cost of the mitigation measures in terms of implementation, operation and maintenance costs, changes in local tax base, displacement of residences, businesses and farms, social costs and negative impacts on other fish and wildlife resources resulting from the mitigation features.

I believe that we should seek a reasonable balance among the engineering, economic, and environmental aspects of Corps projects and permits. However, I do not believe that it is in the public interest for us to mitigate damages at any cost. Working with FWS, EPA, and the National Marine Fisheries Service, we will give high priority to recommending reasonable mitigation and compensation measures particularly where significant fish and wildlife resources are involved.

If project-induced losses are identified, it is first necessary to determine what steps can be taken to modify the project to reduce or eliminate such damages. Where project engineering or other constraints make modification infeasible or inadequate, it is then necessary to identify measures that can help to offset losses.

Examples of mitigation measures recommended by the Corps may include: changes in project layout or size; storage to maintain minimum streamflows for fisheries; fish hatcheries and fish stocking activities to be operated and maintained by the appropriate fisheries agency; initial development and more intensive management of existing Federal lands; phased development of lands concurrently with authorized project expansions; and land acquisition.

A proposal to acquire additional land for mitigation usually generates significant controversy. Taking large amounts of land out of private ownership may cause local economic impacts (losses in local tax base, displacement of residences, businesses and farms, social costs, negative impacts on other resources) which, by any reasonable standard, could outweigh the value of the fish and wildlife resources affected. These adverse impacts must be considered. One promising method of overcoming some of the problems encountered in large land takings, and one which I feel should be pursued where possible, is the intensive management of lands acquired and of existing public lands for fish and wildlife purposes. However, each decision, whether it involves land acquisition or a change in project size or some other mitigation measure must be made on a case-by-case basis considering both the tangible and the intangible benefits and costs of implementing the mitigation features.

When the construction agency decides on the extent of justifiable mitigation measures, it is necessary to determine which agency, Federal or local, is to be responsible for operation and maintenance. It is the policy f the Corps to operate and maintain any fish nd wildlife features such as fish ladders hich are integral to the operation of the roject, and we are doing this at many sites. owever, for non-integral facilities, such as ish hatcheries and off-project lands, the WS, the National Marine Fisheries Service and tate agencies (and even the Forest Service nd the Bureau of Land Management in some ircumstances) are really better trained and quipped to manage facilities for fish and ildlife purposes. I believe that in most ases these agencies should be assigned esponsibility for operation and maintenance f mitigation features. If a state agency ill not assume maintenance responsibility, uthorization reports should recommend ssignment to an appropriate Federal agency. gencies will accept if funds and other esources are made available.

Currently, three areas are controversial. unding requirements for operation and aintenance of mitigation measures has been matter of contention for years. We have elt that the operating agency is in the best osition to formulate priorities and justify udget requests for hatcheries and land anagement measures. Under the proposed egulations, if adopted in their present form, unding will be provided by the construction gency. This will require more detailed anagement agreements and compliance reporting n order to enable the construction agencies o justify budget requests for operation and aintenance.

Another matter of contention regarding itigation measures has been the timing of and acquisition. Charges have been made that he Corps delays acquisition of mitigation ands until too late. This procedure may lead o failure of the mitigation purpose since the ands may be cleared concurrently with, or in nticipation of, project construction. To esolve this issue we issued guidance to our ield offices last year to buy authorized itigation lands concurrently with land for ther purposes. We were pleased to see this principle endorsed in President Carter's water policy statement.

Third, with respect to the method of land acquisition, it has been charged that we are reluctant to condemn land for mitigation and that we are too dependent on finding a willing seller. That is not our position. It is our policy to use the power of eminent domain as required to insure success of an acquisition task. Without this power we cannot do the job expected of us. We only restrict ourselves to willing buyer-willing seller or easement estates in land for mitigation in the most exceptional cases, or when directed, contrary to our recommendations, by the Congress.

* * * * *

America has evolved through the different eras of its 203 years. The Corps, which can trace its genesis to the founding of the Nation, has also reacted to change, positively altering its attitudes, organization, and program objectives. While we have often been praised for our stronger commitment to environmental concerns, we have more often been surrounded by criticism and controversy.

Our motto is "Essayons," "Let us Try." In many ways we have succeeded. But, I think we can do more. We must ensure that national economic development balances with environmental quality needs. This will require a team effort--between the engineer and the biologist, between the development-oriented agencies and those whose primary mission is preservation of the environment.

Society must progress along a new course, a course marked by balance and compromise. The Corps will continue to try to balance the strong pressures which come from many different directions for the good of all. And, as we support and implement the President's recent directives, we will continue our commitment to meet the needs and desires of the public.

Mitigation in Our Future[1]

Lynn Greenwalt[2]

Mitigation - the magical word of this workshop - inevitably evokes a wide array of emotional response: the crusading zeal of the environmental "hot dogs"; the vigorous, often vague apprehensions of those bent on development; perhaps hurt surprise from some souls who had not encountered the term heretofore -- or its deeper implications for their special project; and finally and fortunately, the dispassionate and detached examination by a truly professional audience such as this one searching for the true National interest!

Before I indulge myself, and favor you, with some useful and productive philosophy on this subject, it is important that we consider together what it is we are talking about. "Mitigation" is defined in the draft regulations on the Fish and Wildlife Coordination Act as (1) "lessening wildlife losses to a project through use of loss prevention measures and (2) offsetting losses through use of other structural and non-structural measures."

This clear definition does not mean that it is our objective to lock up resources in some form of deep freeze; neither does it mean that we supinely accept only the "leavings" of the developers -- those things which make the grade, for example, on some kind of benefit-cost analysis more suited to economics than the environment. Somewhere on this teeter totter running from "lock up" to "leavings" is an appropriate fulcrum -- a point or range below which we cannot accept the loss and above which we will rest content. It is for this comfort zone that we earnestly search and if you can shed light on how we identify that fulcrum, we shall be greatly indebted and long remember the fruits of this seminar! The draft regulations establish a framework within which we can productively seek. They do not, however, establish the formula for precisely telling us when we have arrived.

I would like to set up, and perhaps demolis some basic concepts. First, we like to think that our first priority is to mitigate in kind, on the basis that nature planned wisely in the first place. If deer habitat is destroyed, we should provide substitute deer habitat that accommodates both the displaced deer populatio and the deer population that would be living on the substitute habitat in the absence of th project. If we consider only deer, it is quit possible that we can do that. We have become pretty innovative and ingenious in the management of given species. In this sense, a specie is like other public utilities and values. It is easy to replace the telephone lines or the black top road bisected by a Corps reservoi in most cases we can do as much for the deer herd, given the financial resources and opportunity.

However, we are now moving toward an inter in maintaining ecosystems as well as species. It is difficult, and at times impossible, to replace a destroyed ecosystem - an inundated trout stream or an excavated bass stream are the impossibles. Probables are the plugging o ditches that drain bottomland hardwood and prairie pothole wetlands, and the construction of water control structures at select location to impound water suitable for waterfowl production. Sometimes the action of ecosystem replacement destroys another system of consequ This dilemma must be addressed as we pursue ecosystem mitigation.

What this tells me is that it must be our immediate objective to continue to provide -- substitute habitat where necessary -- for spec of special concern to the State or Nation, striving in this context to provide mitigation in kind. However, concerning the protection o special environments, it is increasingly imperative that we do our best to develop fish and wildlife planning objectives, by watershed or basin, which delineate high value habitats which merit special concern. We must then do the best job of planning possible in integrati such objectives into project plan formulation both to extend and maintain species compositio and diversity, and at the same time keep our e on some larger target -- certain broad wildlife management objectives. So armed, we must offset the very real losses that spring from resource development projects by moving to a compensation philosophy. That philosophy would recognize the difficulty, although not impossibility, of in-kind restitution, and go to (1) tradeoffs as necessary among ecosystems and (2) adamant protection of certain others. That is, our goal must be to insure an ecosystem with the project in place which is as desirable as the ecosystem that would have been there in the absence of that project.

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[1] Paper presented at the Mitigation Symposium, July 16-20, 1979, Colorado State University, Fort Collins, Colorado.

[2] Director, U.S. Fish and Wildlife Service.

How do we arrive at this situation on some objective basis that makes sense not only to the wildlife biologist but also to the planning engineer and economist? What I have said to this point is prelude. But it sets out one of our main philosophical problems as I see it.

Now, the historical perspective. Although Webster and others used the term "mitigation" earlier, the Hon. John Dingell used it in the sense of this seminar in the 1958 Fish and Wildlife Coordination Act. And it is in this context that much of our deliberations are taking place this week. The 1958 Act, in a sense, was the ticket which admitted the State and Federal wildlife agencies into the water resources game. At that time, the real carrot was the prospect of fish and wildlife enhancement benefits -- then consisting of man-days and their attendant dollar values based on recreational fishing, and sometimes hunting. We did provide some substantial fishing values which were useful in justifying boat ramps, multi-level outlets for controlling downstream temperatures, parking lots, and the like so that more people could enjoy flat water fishing -- or in some cases improved river and stream fishing downstream from Federal dams. It also may have helped justify projects by fattening the B-C ratio.

Too often overlooked was the fact that these kinds of benefits were being realized at the same time that damages to such things as bottomland habitats, streams, and induced damages to riparian and estuarine habitats through regularized flows, were being incurred without mitigation. So, we were in the position of giving benefits for a recreational experience that often was becoming more plentiful and therefore less valuable, while allowing the project to damage terrestrial habitats, free-flowing streams, and other environmental amenities without mitigation. Very few acres of land additional to normal project lands were being acquired for mitigation of terrestrial wildlife losses through the 60s and early 70s. The irony of this became evident when, after 1965, State fish and wildlife agencies were asked to cost share enhancement features when substantial uncompensated losses were unattended to! This fact was quickly recognized by perceptive State Directors.

What do we make of the immediate future and where should we take aim? Fortunately, I hope, several actions are in prospect. The Coordination Act Regulations establish some procedural requirements to achieve the equal consideration intent of the Act which should be helpful. The requirements for participation by the wildlife agencies (Federal and State) in the earliest stages of planning will help avoid some of the basic errors in planning before they are so imbedded in plan formulation that changes are difficult to impossible. For example, a minimal change in project location may avert some of the more serious losses.

The requirement that mitigation recommendations be justified by reliance on habitat-based evaluations of losses is important, particularly where land acquisition for substitute habitat is involved. The experience with use of man-day evaluations to justify loss-prevention measures is too well known to bear repeating here, especially where terrestrial species and habitats are involved.

Too often, the fact that mitigation has not been achieved traces to a failure to obtain needed annual operation and maintenance funds for the administering State fish and wildlife agency. The regulations will provide that these be provided by the construction agency. This is right and proper in our view. The project caused the damage. The project beneficiaries should cover the appropriate share of the cost of making whole the loss in their repayment schedules. Those funds go to the Federal Treasury. Then comes the question of which Federal agency includes funds to cover these costs in its budget request for annual appropriations. If the construction agencies fail to include such funds in their requests for other water development program funds, the true costs of the program are hidden from the Congressional decisionmakers who oversee its funding. Specifically, if the Fish and Wildlife Service were to budget these funds, the Congress could not determine the real costs of the water development programs by looking at the public works part of the Federal budget.

The draft regulations also provide for an adequate disclosure of reasons for turning down mitigation recommendations and prohibit the simple statement that they are unjustified on a monetary B-C ratio, that the project purposes do not permit their acceptance and implementation, that beneficiaries are unwilling to pay their share of such costs, and so on.

I encourage your close reading of the regulations if you have not done so. We hope to have final regulations for publication early this fall but have extended the comment period to August 17. We need your comments, both critical and supportive.

The art -- or science -- of evaluation based on habitat values is being advanced by interagency efforts centered here at Fort Collins. This is a crucial endeavor if the new regulations are to be effective. Although the basic approach has been spelled out several years ago -- with the help of many in this audience -- the details necessary to make it fully operational are still being put together. It requires time, skills, and funds. We need additional key criteria handbooks for specific areas.

I want to bring to your attention a recent development which provides special impetus to bring to a rapid conclusion the basic work on aquatic habitats -- both inland and estuarine -- which are lagging the terrestrial effort.

The President's Task Force on Non-Indian Federal Water Rights has released its proposals for public comment. It recommends that, within five years, the President seek funds to quantify all present Federal consumptive water uses on Federal lands in the Western States, and all non-consumptive and reasonably foreseeable future needs for which reserved rights exist, within fifteen years. The draft report recognizes the lag in technology for quantifying non-consumptive instream flow needs, particularly in the areas of riparian habitat needs and of inland wetland maintenance for optimum wildlife productivity.

If the President adopts these proposals and obtains the necessary funds, the competition among Federal land managing agencies for the limited number of instream flow experts will be severe. More important, the quantification effort will demand, and hopefully provide, funds to greatly accelerate the development of instream flow technology. I recommend that you follow these proposals very carefully when they reach the Federal Register. I have asked the Symposium sponsors to make extra copies of the draft report available here today.

You will note from this discussion that these are measures designed to demonstrate more clearly the merit and justice of our recommendations to planners, as well as the whole chain of decisionmakers and the public. It is still discretionary with the action agency as to which of our recommendations are acceptable. While many recommendations are rather self-evident to us, the question of whether they are "justified" are not so evident to the action agency decision maker. We are, in the regulations, however, asking from him a rather detailed disclosure of why he did not accept our recommendations. It is equally important that we provide sufficient backup for our recommendations so that he can act on the basis of informed judgment. The back-of-the envelope approach will not suffice.

The conclusion I reach, then, boils down to several fundamental steps which I believe are becoming discernible in the crystal ball. I like Larry Jahn's basic concepts of identification of important habitats, delineation of the impacts, and actions to insure the maintenance of important habitat values. To do this adequately and effectively, I would hope some day that we can proceed along these lines:

First: Develop certain habitat based goals and objectives by area.

Second: Develop inventory information that is adequate and current. Our Office of Biological Services is working hard to develop useful wetland inventories, instream flow criteria descriptive characterizations of critical areas, quick access technology and methods for the biologist-planner to quickly retrieve the needed information for his assessment of project impact.

Third: Attain early and continuing entry and, most important, acceptance into the planning process of the action agencies -- not to be obstructionist but to make their life easier in terms of the volume of flak received later. And above all, comprehensive planning requires it.

Finally: Be assured that the measures recommended and accepted are installed in timely fashion and that, once installed, they are effective in terms of anticipated results.

In short, I would underscore the importance of participating early in planning so that the project will have been so designed that many of the fish and wildlife features are fairly homogeneous -- factory installed options, if you will. This has to do with such matters as locating and sizing the project, determining the general features and whether the irrigation diversion goes through a productive wetland or along a contour -- these kinds of basic decisions often have more effect in terms of limiting losses than the later and more conspicuous changes and add-ons. We should have the scientific and technical backup for our biologists which puts them on a par with the planners more steeped in engineering and economics. The economists and engineers are generally blessed with data accumulation over years. We are not. Of great importance is the inclusion of the public in the planning process and in the follow-on discussions before the decisionmakers. One of the big reasons that the construction agencies are successful in their interest in the tangible economic benefits of project construction. You may question, of course, whether all of those benefits are National in character but the Principles and Standards, if properly implemented, will delineate the differences between National and local or private benefits.

I conclude, then, that our future is in training and equipping our people with modern tools and information, becoming more involved early-on in the planning process, and otherwise following through to insure that recommendations are implemented in a timely fashion. We are not going to go much further in the old reactive mode. But a positive approach, based on integrity and facts, will do much to achieve the equal consideration doctrine of the Fish and Wildlife Coordination Act.

To close on a scriptural note, and with sincere apologies to St. Paul, I would paraphrase my faith in the future of our subject as "mitigation is the substance of things hoped for, the evidence of things not yet seen clearly but devoutly to be hoped for!"

Current Policies and Programs Relating to Mitigation of Fish and Wildlife Habitat Losses[1]

Ben D. Jaco[2]

Abstract.--Beginning with its first project, Norris Dam, TVA has directed its efforts toward assuring the maximum benefit for all resources by careful coordination of the varied interests and potential uses at each stage of development--planning, construction, and operation. Examples are given of various alternative measures that TVA has employed in recent years for fish and wildlife benefit.

The TVA Act of 1933 provides the Tennessee Valley Authority with broad and unique responsibilities for promoting resource development. Specifically, we are charged with improving the navigability and providing flood control of the Tennessee River, providing for reforestation and proper use of marginal land, providing for agricultural and industrial development, and certain other land-rights for National defense within the Tennessee Valley. TVA is a corporate Agency of the Federal government, possessing much of the flexibility of a private enterprise It has made extensive use of this flexibility.

More specifically, TVA is charged with the planning and implementation of human and natural resource development programs on lands it holds and manages in cooperation with local, State, and Federal agencies, private landowners, and corporate entities. It acts within a 125-county, 40,910 square mile area incorporating portions of the States of Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia. The Agency operates a system of multipurpose water resource projects which create both warm- and cold-water reservoirs covering 620,000 surface acres with 11,000 miles of shoreline. Thirty-eight thousand miles of stream feed them. TVA's electrical system encompasses 17,000 miles (over 200,000 acres) of transmission line rights of way. It is TVA's policies on management of the fish and wildlife on these lands and waters that I address today.

From its earliest days, TVA has viewed fish and wildlife as an integral part of its planning, construction, and operations. At the time TVA began building dams it was widely predicted that reservoirs would soon become "biological deserts" and go from an early "boom" to an eventual "bust" (Cahn, 1937; Ellis, 1937). To offset, or in terms of this symposium, to "mitigate" for the expected loss, TVA, together with what is now the U.S. Fish and Wildlife Service, developed two fish hatcheries to guarantee fish for each of its first two reservoirs; Wheeler on the Tennessee River in north Alabama, and Norris on the Clinch River in east Tennessee. In 1936, the year these reservoirs were impounded, TVA announced formation of a reservoir study group at the annual meeting of the American Fisheries Society (Cahn, 1937). Although this early group was formed primarily to prevent biological catastrophies, it soon evolved into an innovativ fisheries research team which was recently described by R. H. Stroud as being first to integrate ecological information with fisheries management objectives designed to benefit resource users without harm to the resource base. This was one of the earliest, perhaps the first such ecosystem approach in fisheries science (Stroud, 1978). TVA continues this practice in its fish and wildlife research, management, and mitigation.

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[1] Paper presented at the National Workshop on Mitigation Losses of Fish and Wildlife Habitats, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

[2] Specialist, Agency Coordination, Fisheries and Aquatic Ecology Branch, Tennessee Valley Authority, Knoxville, Tennessee.

In the 1930's and 1940's, TVA wildlife biologists, with other Federal and the few existing Valley State wildlife managers, were also planning toward wildlife enhancement on TVA reservoir lands. In 1939, TVA set aside its first land dedicated to wildlife by making 8,338 acres of land and water on Wheeler Reservoir available to the Bureau of Sport Fish and Wildlife to form the 35,235 acre Wheeler National Wildlife Refuge. Today, nearly 200,000 acres of TVA land and waters are managed for fish and wildlife by other Federal and State agencies. (Table 1)

From these early beginnings came vigorous, innovative approaches to fish and wildlife management, some of which will be mentioned later. Tennessee Valley State game and fish agencies have progressed to highly professional organizations in which the ownership and management of all Valley resident fish and wildlife is vested.

Public attitudes have also changed drastically from the early one of welcoming the creation of reservoirs to the present one of finding further such construction offensive. We have also moved from a time when land and water, though poor in quality, was available in quantities exceeding fish and wildlife user needs to one in which benefits for competing uses are perceived as so valuable by resource decision makers that just retaining the public land and waters managed for fish and wildlife has become a task consuming much of our time and fiscal resources. The thrust and scope of fish and wildlife programs have changed accordingly. Today, TVA's staff of 136 fish and wildlife professionals spend more than half of their time and funds to protect the resource by monitoring the effect of ongoing activities and investigating the impact potential of future projects.

Table 1.--TVA land and water used for Federal and State wildlife programs[1]

Agency	Reservoir	Acres		
		Land	Water[2]	Total
U.S. Fish and Wildlife Service:				
Tennessee National Wildlife Refuge	Kentucky	10,110	45,175	55,285
Wheeler National Wildlife Refuge	Wheeler	8,318	26,917	35,235
State of Alabama	Guntersville	5,040	19,962	25,002
	Pickwick	7,103	2,318	9,421
	Wheeler	2,515	6,963	9,478
State of Mississippi	Pickwick	1,375	222	1,597
State of Tennessee	Chickamauga	3,873	5,472	9,345
	Douglas	184	1,046	1,230
	Norris	26,750	799	27,549[3]
	Watts Bar	674	3,927	4,601
	Kentucky	275	11,530	11,805
	John Sevier Steam Plant Reservation	224	168	392
	Kingston Steam Plant Peninsula	835	1,010	1,845
	Normandy	850	-	850
State of Kentucky	Kentucky	9	3,265	3,274
	Shawnee Steam Plant Reservation	1,395	-	1,395
TOTALS		69,530	128,774	198,304

[1] Does not include TVA programs such as LBL and Nolichucky.
[2] Includes both land and water below maximum shoreline contour, and the entire area is subject to permanent or periodic flooding.
[3] Includes two multipurpose recreation-conservation areas--Central Peninsula and Cove Creek Peninsula.

As many of you know, TVA has never been under the Fish and Wildlife Coordination Act provisions. The professional fish and wildlife staff is a voluntary creation of the Agency to deal with the concerns in this area inherent in the construction and management of the TVA reservoirs. Its assigned goal was and is to work with Valley State fish and wildlife agencies and various other local, State, and Federal agencies to enhance or offset, or reduce fish and wildlife impacts resulting from TVA activities and projects.

Through the years many attempts have been made to place TVA under provisions of the Fish and Wildlife Coordination Act but none was implemented, probably because TVA was recognized as a multiple resource-development agency responsible for all the resources of the Tennessee Valley Region. Today this is probably quite academic since all Federal agencies are governed by a series of laws and regulations requiring detailed examinations of project impacts on fish and wildlife. I refer specifically to the National Environmental Protection Act (1969), the Federal Water Pollution Control Act (1972) together with its 401 and 404 permit requirements, the Surface Mining Control and Reclamation Act (1967) and the Endangered Species Act (1973). In addition, the Agency has Memoranda of Understanding with all seven Valley State fish and wildlife agencies for coordinating, problem solving, and cooperative efforts. Since 1969, we have maintained a Memorandum of Understanding with the U.S. Fish and Wildlife Service which provides for annual review of water resource projects by the U.S. Fish and Wildlife Service and Valley fish and wildlife agencies.

Internally, TVA has always considered fish and wildlife impacts in the decision-making process in feasibility studies, design plans, and in construction and operations to prevent losses, minimize impacts, and design fish and wildlife improvements. Here too, both its own and other Federal and State biologists participate.

Within its statutory limitations, TVA now provides minimum flows below dams, reaeration of water discharged with low dissolved oxygen levels, stabilization of reservoir levels for fish spawning, dewatering of specific marginal areas for waterfowl and related faunal development, subsidized wildlife habitat development of powerline rights of way and development of construction project alterations or additions to meet day to day fish and wildlife needs. All are fish and wildlife mitigative measures.

You are already familiar with the standard mitigation practiced by fish and wildlife and contruction agencies so I will devote the remainder of my time to what I consider recent innovative efforts by TVA.

The first is TVA's Land Between The Lakes, the U.S. Corps of Engineers creation of Barkley Reservoir with its connecting canal to TVA's Kentucky Reservoir, virtually isolated a 170,000 acre peninsula of sparsely populated, low-value land in western Tennessee and Kentucky. In 1963, TVA was assigned the area, named it the Land Between The Lakes, and begun a continuing recreation and environmental education development and demonstration project to maximize utilization of the region's available resources. This utilization includes fish, wetland and upland wildlife research and management.

In east Tennessee, the single-purpose Nolichucky hydro-power project built by a private power company in 1913, created a six-mile long lake of about 400 acres. This lake and its shoreline was acquired by TVA in 1945. By 1970, silt from mining operations far upstream on its watershed had filled the reservoir to a point where power benefits no longer justified maintenance and operating costs; TVA strengthened the dam for safety, converted the powerhouse and equipment to a regional Environmental Education Center and dedicated its land and water area to the enhancement of migrating and resident waterfowl, fisheries and upland small game, and environmental education.

Bear Creek in northwest Alabama and northeast Mississippi, is a small stream with a large watershed and a long record of annual flooding. TVA and Bear Creek Watershed Authority, a legally established State agency, constructed four small reservoirs and a floodway for flood control, water supply, improved water quality, and recreation. As originally planned, the project included channelization of 18 miles of the creek. District, State, and Federal biologists, together with design engineers, devised a nine-mile floodway roughly parallel to, but at a higher elevation than Bear Creek. This channel was designed to carry water only during flood periods. It crosses the creek at several locations, protected from erosion by concrete sills. Except at the crossings the creek and its riparian vegetation were left intact.

In northeast Alabama, at a TVA coal-fired steam electric generating plant, the need for additional wet storage for ashes had become acute. Terrain and safety requirements dictated that an embayment and an adjacent stream, Widows Creek, be included within the pond and dike. Investigations showed that this portion of the stream served as a valuable spawning area for white crappie and largemouth bass from Guntersville Reservoir. It also provided good early spring fishing for these two species. Engineers and biologists working together, designed a replacement stream and embayment similar in characteristics, including both stream length and deep water/shallow water ratio. In addition, improved fishermen access was provided.

Near a small town in middle Tennessee, a 3,100 acre flood control water supply-recreation reservoir, Normandy, was planned. Preliminary studies predicted a stratified reservoir with a cold, sometimes oxygen-depleted hypolyminion. Engineers and biologists combined talents to design and install equipment which allowed multilevel withdrawal for mixing and temperature control coupled with sleeve valves to produce discharges with nearly saturated oxygen levels. The result is a 14-mile tailwater area with minimum instantaneous flows and temperatures regulated for optimum trout growth. This reach of the Duck River, which formerly provided rather sporadic coolwater fishing now has recreational floating, fishing, and upgraded water quality for downstream municipal uses. The coolwater fishing further downstream has been enhanced.

In addition, TVA mapmakers combined abilities and knowledge with TVA and Tennessee Wildlife Resources Agency biologists to produce a unique navigation-recreation map for Normandy Reservoir users. It shows all shoreline features such as forest cover, roads, recreation areas, and water management areas in detail. From aerial photos, roads, culverts rocks, caves, springs, trees, stumps, and other underwater structures and features used by fishermen were precisely located on a 1:24,000 scale topographic map.

At Briceville, a small coal mining town in east Tennessee, Coal Creek, a small, mountainous stream which offered no viable flood control alternative was channeled to provide a floodway for recurring dangerous local floods. The channel was produced by cutting and filling on only one side of the creek. Even though excavating and channel realignment moved from bank to bank at various locations, trees, brush, and grasses on the other bank were left undisturbed. The resculptured bank was then replanted to tall grass and trees which offer little resistance to flood flows. Gabions were installed to redirect flows and scour instream pools. This addition complements the shade provided by undisturbed trees and shrubs to provide temperature control and fish shelter until the regrowth of new stream bank vegetation.

TVA usually purchases rights of way for its powerlines. Fee title to land over which they run remains with the private landowner. For many years, TVA routinely cut or treated rights of way with herbicides; the results were often unsightly scars on the landscape and temporarily barren bands of land. TVA has devised a plan whereby the private landowner can be paid a fee to help cover seed, fertilizer, and basic cultivation costs in return for conversion and maintenance of the right of way to low growing wildlife habitat.

On the Hiwassee River in east Tennessee, a large newsprint producer needed additional effluent lagoon space to improve water quality. Both the company and fish and wildlife resources would benefit thereby, but the only feasible area for the lagoon was an embayment valuable for fish spawning, waterfowl, wading birds, and miscellaneous small animals and plants. Mitigation as agreed upon by the TWRA, TVA, and USFWS, took two major forms. First, a 10-acre striped bass rearing pond facility was designed by TWRA and built by the company. The fingerlings reared can either be released directly into Chickamauga Reservoir or collected and trucked for stocking in other reservoirs. Second, a 50-acre lateral subimpoundment complete with pumping and dewatering facilities was developed to allow complete control of water levels for migratory waterfowl management. Both areas lie within a State-managed wildlife area on TVA reservoir lands, but on the same river from which the embayment was used.

In conclusion, the TVA experience has been a revolutionary and innovative blend of cooperative planning, research, and construction to enhance TVA projects' fish and wildlife benefits and mitigate the fish and wildlife losses.

Banquet Address:

The Role of the Water Resources[1] Council in Inter-Agency Coordination

Leo M. Eisel[2]

I'm always somewhat undecided about what to say at banquet speeches. On one hand, I know that all of you have been listening to serious speeches all day, and probably the last thing you want to hear is another serious speech. You would probably like some entertaining remarks--and brief remarks at that. However, it's not very often that an engineer has the opportunity to return to his Alma Mater and speak to a large group of professionals concerned with one of our most pressing natural resources problems: the preservation and enhancement of the Nation's wildlife habitat in the face of ever increasing demand for more energy, more water, more highways, more homes, and more of everything. Consequently, I'm going to take the opportunity this evening to speak to this problem and hopefully make the point that if these demands for more of everything are to be met, either through conservation, or an increase in supply--and the Nation's wildlife hatitat is to be maintained and improved--changes must take place in our planning, design, construction, and management programs for natural resources.

First, let me tell you about the United States Water Resources Council. We aren't a very big or very well known agency and I always like to take the opportunity to explain who we are and what we do. The Council was established in 1965 by the Water Resources Planning Act. The Members of the Council are the heads of the eight major Federal Departments or Agencies with responsibility for water resources programs--Agriculture, Army, Commerce, Energy, Housing and Urban Development, Interior, Transportation, and the Environmental Protection Agency. The Council's Chairman is appointed by the President from among the Members.

The major function is to provide the mechanism for interagency coordination of water resources policy and programs. Aside from the coordination function, the Council also has other congressionally mandated responsibilities. For example, we provide a regular assessment of the Nation's water resources and their adequacy for meeting present and future demands.

A major program of the Council has been to establish the Principles and Standards for Water and Related Land Resources Projects. Essentially, the Principles and Standards consis of a set of procedures and rules for use by Federal water agencies in planning and evaluatin Federal water projects. The Principles and Standards establish a consistent and uniform approach to benefit cost analysis for use by Federal agencies. I will return to the Principles and Standards a little later.

The Council prepares regional assessments of the impact on water resources of the emerging energy technologies, such as geothermal oil from shale, gas and liquids from coal, biomass conversion and small scale hydroelectric In preparing the water for energy assessments, an important consideration is instream flow for fish and wildlife.

The Council has a number of other responsibilities which I will not touch upon. In its 14 years of existence, the Water Resources Council (WRC) has been criticized as a "do-nothing" organization. I believe that much of this criticism was well deserved. The Water Resources Council, however, suffers from many of the same problems which are inherent in any regional government, or intergovernmental organization. These problems result from the reluctance of the members of these organizations whether they be cities, counties, states, or federal agencies, to give up sufficient authorit to the intergovernmental or regional entity to allow it to do the job for which it was originally formed. However, much of this can be solved with strong support from the top--and the Water Resources Council has received this support and interest from President Carter.

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[1] Banquet Address at the Mitigation Symposium, July 18, 1979, Colorado State University, Fort Collins, Colorado.

[2] Director, Water Resources Council, Washington, D.C.

As a result, I believe the WRC is today doing the job originally intended by the 1965 Act.

Now that I've explained a little about the Water Resources Council, I'd like to discuss briefly a common link between many of you here and the Water Resources Council. The common link is the Fish and Wildlife Coordination Act which is closely related to water. In fact, the only mandatory provisions of the original Act passed in 1934 dealt with water-related concerns. The 1934 Act required consultation with the Bureau of Fisheries prior to dam construction to determine if fish ladders, as aids to fish migration, were necessary or economically practical. In 1946, the Act was amended to include consultation on any impoundment, diversion or control of any stream or body of water for any purpose by any Federal agency or by an public or private agency under Federal permit to prevent "loss of and damage to wildlife resources."

In 1958, the Fish and Wildlife Coordination Act was again given a major legislative overhaul. The most essential change was to require that wildlife conservation be given equal consideration with other features of water resource development. Water and wildlife habitat are, therefore, closely connected, not only in practice, but also through Federal statutes such as the Fish and Wildlife Coordination Act.

The Fish and Wildlife Coordination Act, however, is not an adequate tool by itself to solve the many conflicts between preservation of wildlife resources, and the pressure for increased water resources development which are occurring and will continue to increase in the future. If these water resources problems are to be solved without continued destruction of wildlife habitat and resources--then substantial efforts outside the limits of the Coordination Act must occur.

In order to better understand these conflicts between water development and wildlife, I'd like to give you just a brief overview of the Nation's present and future water problems so that you have some feeling of the magnitude of these problems. For example, we recently divided the Nation into 106 river basin areas for purposes of the Second National Water Assessment. Of these 106 river basin areas, and these are large basins, for example the entire Platte River Basin is one, 17 of these 106 have or will have a serious problem of inadequate surface water supply by the year 2000. This means that more surface water is presently demanded or will be demanded than presently flows in the stream in the average year. These 17 areas mainly exist in the Midwest and Southwest. Serious fish and wildlife problems already exist and will continue to worsen in many of these areas. For example, the Lower Colorado River has an average flow of 1550 mgd, well below the 7000 mdg considered ideal for fish habitat.

I could go on and on here regaling you with lots of ominous sounding facts, figures and future projections. The point, however, is that serious problems exist concerning our Nation's water resources and that it will take more than the Fish and Wildlife Coordination Act and mitigation to insure the preservation and enhancement of wildlife habitat. In short, wildlife and wildlife habitat are intimately bound up with water resources management and development. If these wildlife resources are to be preserved, then an effort which far exceeds the bounds of the Fish and Wildlife Coordination Act must take place.

This expanded effort involves many of the changes in water policy and programs directed by President Carter in his recent water policy review.

The President's water policy review began with his environmental message of May 1977 which directed the Office of Management and Budget, the Council on Environmental Quality, and the Water Resources Council to review Federal water policies and programs and make recommendations for change.

Many of the President's directives resulting from the water policy review are vitally necessary for improved management and enhancement of our wildlife. For example, the President's directive of July 12, 1978, stemming from the water policy study, requires promulgation of regulations "defining the requirements and procedures that must be met for fully complying with the Fish and Wildlife Coordination Act." The directive included a provision that "agencies shall include the designated funds for all environmental mitigation for the project and shall require that mitigation funds be spent concurrently and proportionately with construction funds throughout the life of the project."

Instream flows, of course, are vital to fish and wildlife habitat. However, the water laws which affect instream flow, are state laws, and so the states have primary responsibility and authority in this area. President Carter directed that federal agencies, in cooperation with the states, would improve operation and management of existing water projects to protect instream uses. The President has also asked Congress to increase the Water Resources Council's grant program to the states from $3 million yearly for water planning assistance to $50 million yearly for water management and water conservation technical assistance. I believe this can assist the states to improve many of the problems associated with instream flow, as well as to take important steps in conservatio- methods which can also improve the instream flow picture.

The President has directed the Council to revise the Principles and Standards for Planning Water and Related Land Resources Projects. I mentioned the Principles and Standards earlier, and want to tell you a bit more about them now, since they also relate to efforts to improve our mitigation procedures.

The President's water policy directives instructed revision of the Principles and Standards to include greater emphasis on nonstructural alternatives to projects and greater emphasis on water conservation. Both, of course, impact mitigation and instream flow. The Council has proposed the revisions. They have been published for review and comment in the Federal Register on May 24, 1979, and the comment period closes on July 27. We have had several public meetings, including one yesterday in Washington, D.C., and one on July 10 in Los Angeles, to receive oral comments, and we are receiving written comments as well.

The proposed changes to the Principles and Standards clarify and emphasize the breadth of alternatives which planners are to consider in formulating projects. Demand reduction strategies, as well as strategies which will result in improved efficiency of resource use, are to be considered equally with proposals for increasing supplies. Formulation of a primarily nonstructural alternative will be required whenever structural program or project alternatives are considered.

If future demand increases for more water, more flood control projects, and so forth are to be reduced, then these efforts to promote water conservation and nonstructural measures are vital.

I am very concerned about recent actions by two House Congressional Committees, both of which affect the Principles and Standards. First, the House Committee on Public Works and Transportation has effectively established a veto over the changes to the Principles and Standards. The Council may promulgate changes, but the changes will only become effective if the Congress doesn't adopt concurrent resolutions disapproving the changes. I realize that no mere bureaucrat should try to explain to the Congress what it will or will not do, but I just don't believe that the Members of Congress in the midst of SALT II, the energy crises or whatever, will be likely to sit down and responsibly debate the merits of the Principles and Standards. What I am afraid will happen is that a very few members will be fired up by a narrow interest group, and such a resolution will be adopted with very little attention on the part of the other members. The House Committee on Agriculture also adopted language dealing with the Principles and Standards. This Committee has exempted from the Principles and Standards those small watershed projects of the Soil Conservation Service which do not involve single structures providing more than four thousand acre-feet of total capacity. This has the effect of eliminating many stream channelization projects from the scrutiny of the Principles and Standards. This simply weakens the Principles and Standards and thus weakens the provisions which help to provide the protection measures we are all interested in. The actions by these two committees are not yet law--they must be voted on by the full Congress.

President Carter, as a part of his water policy recommendations, also directed the Council to prepare a Manual of Procedures for Evaluating Benefits and Costs of Federal Water Resources Projects. The first portion of the Manual was published in the Federal Register on May 24, 1979, as proposed rules and regulations, subject to public comment until July 27. The purpose of the Manual is to insure that the Federal water development agencies use the best possible benefit/cost analysis and other planning procedures.

The Council is also starting to develop a second section of the Manual which will deal with environmental quality evaluation procedures. This will involve the development of procedures for evaluating the beneficial and adverse effects of federal water projects on environmental quality. The Procedures will be published for public review as rules and regulations in the Federal Register. We expect to complete this in approximately one year.

The Environmental Quality section of the Manual of Procedures will be of great interest to all of us--certainly I hope that it receives more attention than the section on national economic development. In the section on environmental quality, the Council will be able to pull together the many mitigation issues which have been needed so long. To beg your indulgence for just a while longer, I'd like to mention some of the issues which this section of the Manual will address that are of deep concern to everyone here.

The environmental quality section will address how we plan for concurrent and proportionate mitigation. We have received excellent help from the Fish and Wildlife Service in beginning to develop these procedures. The Fish and Wildlife Coordination Act calls for a "habitat based" approach for the evaluation of impacts to fish and wildlife resources, and the Fish and Wildlife Service has developed an approach which is now being tested and revised. The Water Resources Council has financially supported some of this work.

We also expect to address the minimum flow concept in the second section of the Manual. The Cooperative Instream Flow Service Group in Fort Collins has made important strides in the development and refinement of instream flow methodology. The group has developed an analytical framework for evaluating the impact on fish habitat of incremental changes in the hydrograph over an annual cycle. The approach is being tested across the country, and I understand that the early results are good. The early analysis indicates high correlation between the habitat units predicted by the methodology and actual standing crop of fish. We hope to include some of this work in the Principles and Standards Manual.

Finally, I want to turn to another effort of President Carter's to provide greater impetus to improvements in the management of our water resources. By Executive Order, President Carter directed the Water Resources Council to begin on April 1, 1979, an independent water project review function. The reviews would be on the technical aspects of a planned project and would replace the Office of Management and Budget's technical reviews which had both unknown criteria and undetermined duration. Essentially, the Water Resources Council staff, taking no more than 90 days, would prepare reports on proposed projects which would be transmitted to the head of the involved agency who would then send the statement along with the project report to the Office of Management and Budget. The Office of Management and Budget would not accept project reports without such statements.

The basic purpose of this review is to ensure compliance by the Federal water development agencies with the Principles and Standards, the Fish and Wildlife Coordination Act, NEPA and other Federal laws and regulations.

I believe that the proposed independent water project review function will not only assist with these statutes and regulations in assuring compliance; it will also insure that necessary water projects will be built sooner, by avoiding lengthy Office of Management and Budget reviews and lengthy and costly lawsuits.

To begin the reviews by the April 1 deadline, the Council required permission from the House and Senate to reprogram FY 1979 funds to provide the necessary staffing. The Senate Appropriations Subcommittee approved reprogramming, but the House Appropriations Subcommittee did not. I am personally very disappointed by this congressional action since it is frustrating a significant step forward in improving the management of our nation's water resources and the consequent protection of our wildlife resources.

I guess the last issue could be a question--have we made any progress toward providing the institutional framework for improved mitigation? I think that we have. Like most progress, it hasn't come fast enough or exactly as we want, but there has been progress. Most of that progress helps to bulwark the mitigation requirements provided by the Fish and Wildlife Coordination Act. The Act has been a stepchild for several years but I believe a new era is dawning for its effective implementation. It will take a lot of people from essentially every federal agency to see that there is compliance with the letter and the spirit of the Act. The Water Resources Council, as an interagency policy coordination function, will play a key role in achieving this compliance.

The Biological Basis for Estuarine Ecosystem Mitigation[1]

Edward T. LaRoe[2]

The objective of mitigation should be to protect and maintain the variety of benefits produced by the estuarine ecosystem. Mitigation efforts cannot be based on a single factor, such as productivity, but must incorporate comprehensive consideration of the critical processes and features of the ecosystem, including surface area, flushing, and biological diversity. The selection of appropriate mitigation actions must balance the resources and functions lost with those to be provided.

Mitigation is a concept with a firm foundation in law. It is only within the past decade, however, that the practice of mitigation has been applied with any regularity to projects which affect fish and wildlife resources. While there is now a general consensus that mitigation is a desirable activity and a valid requirement for many kinds of projects, there is at this time little common agreement about what constitutes mitigation, how it should be applied in practice, or even what the objectives of mitigation efforts should be.

I would like to discuss the concept of mitigation as applied to projects in coastal estuaries and wetlands, particularly as it has evolved in Oregon and California. While I am sure some may disagree with this concept, I hope this discussion will lead to some common understanding of what mitigation is, so that it can be applied rationally and soundly in the future.

Mitigation is a term in vogue. Developers -- public or private -- are learning that they have a better chance of securing approval of a permit if they "mitigate." Yet there is often little or no real understanding of what that is. Further, there is often little agreement among the regulatory agencies about what constitutes appropriate or valid mitigation. As a result the concept of mitigation, which I feel is extremely important, is being adulterated. It is confused, particularly, with conservation -- the wise management of our natural resources.

Several examples of mitigation have been described. These included, in part, the design and planning of projects to avoid unnecessary or unwanted impacts; the acquisition or protection of lands in turn for the loss of others; and the denial of a permit. All of these -- planning, acquisition, regulation -- are examples or tools of conservation. They are necessary and appropriate means to manage our resources; but they are not mitigation. Mitigation, too, is a tool of conservation, but we must distinguish between mitigation and the array of other tools for conservation.

Mitigation, as I use the term, is an action or actions to compensate for the unavoidable adverse impacts associated with a particular activity -- generally a development project -- by man. It is an effort to protect and maintain the natural ecosystem, and its objectives should be to maintain the functions, values, and benefits which that ecosystem provides.

Thus, the denial of a permit is regulation, not mitigation. The review of a plan or proposal to suggest changes that reduce the adverse impacts on fish and wildlife is simply good planning, not mitigation.

There are two basic techniques of mitigation compensation and restoration. Compensation is the in-kind replacement, for example by the *de novo* creation of estuarine areas or wetlands out of uplands, of those parts of the wetland ecosystem which were lost. Another form of compensation would involve the removal of a stress (for example, a pollutant load) equivalent to one being added.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

[2] The Coastal Society, Tallahassee, Florida.

Restoration is the rehabilitation and return of part of the ecosystem, formerly altered or removed from the estuary, back to effective productivity. These techniques may differ somewhat from the concept of mitigation as applied to inland areas, but, as I will discuss later, that may be appropriate.

This concept of mitigation -- compensation and restoration -- is the concept as formally adopted by state regulation in Oregon, and as practiced in California. Although this concept could be used to mitigate all kinds of adverse impacts on coastal wetlands, including for example, the addition of a new source of pollution to an estuary, Oregon has confined its application only to dredge and fill activities.

Oregon has described several kinds of actions which might be considered appropriate for mitigation. These include the creation of new estuarine area by shaving spoil islands so that the surface is lowered from uplands to an intertidal elevation; this effectively adds to the surface area of the estuary. Other examples include restoration to effective tidal circulation and estuarine productivity of former tidal marshes which have been diked for agricultural or mosquito control purposes; or the restoration or enhancement of circulation in areas where tidal circulation has been impeded through the construction of solid fill causeways, by the addition of culverts through the causeways. Another example could include the plugging of drainage ditches or canals which alter the natural hydrologic conditions, or the restoration of circulation to oxbows which have been isolated by channelization and spoil disposal projects.

All of these involve positive actions which effectively add to the estuarine ecosystem. The objective of mitigation should be to ensure that the remedial action is of sufficient size and properly designed so as to offset the adverse impacts of the proposed project.

In this concept, mitigation is a means -- the ultimate means -- for the internalization of all costs associated with a project. The losses to the public -- losses in terms of fish and wildlife, recreation, navigation; the present opportunities which the public would otherwise have had to forego as a result of the project -- are prevented by the mitigation action which replaces or restores those benefits. It is a way of saying that we have lost too much of our estuarine values; we will allow no further loss. Whenever a project will cause a reduction or loss of estuarine values, the project sponsor must create or restore an equivalent part of the ecosystem to compensate for the loss.

The most difficult problem at this time is the determination of what kind of action is appropriate and how much mitigation is adequate. These are the problems now being encountered as the Oregon requirement is applied. If, for example, a developer is going to mitigate a 30-acre fill on sandy bottom by restoring a diked former tidal marsh back to effective circulation, how big should be the marsh which he is to restore? Can you substitute equal surface areas, equal tidal prisms, or equal biological productivity? If the two areas have different elevations or ecosystems, how can they be equated?

There is at this time no easy answer; I would like to suggest that it is not an easy task. There is great pressure from the elected politicians and the engineers to come up with some easy formula, some magical way to juggle numbers. I would urge you to resist that temptation. The problem can only be resolved qualitatively, through negotiation, rather than some simple quantitative approach.

The question must be addressed by looking at the ecosystem that is affected, the benefits which that system provides, and the means by which those are produced. The solution will reside in requiring that the ecosystem's processes, its dynamics, and its habitat are all retained.

Although we can not provide a specific formula for the design and approval of mitigation projects, we can begin to offer several general guidelines which might help decide what kind and how much mitigation is appropriate. First, it is important to recognize the full range of benefits provided by the ecosystem. Estuaries and coastal wetlands provide fish and wildlife habitat and the basis for enormous biological productivity. They also provide extensive opportunities for recreation, and serve as routes for transportation of marine organisms (particularly larval forms and juveniles) as well as for man's products. They produce and trap nutrients, absorb and filter natural and man-made pollutants, and flush wastes out to sea. They absorb storm waves and flood waters, thus buffering man and nature from hurricanes and coastal storms. Finally, they serve to moderate the climate, reducing the temperature extremes.

Mitigation efforts should be designed to protect and maintain the full range of benefits to man as well as to fish and wildlife. In order to do this, one must understand what features of the ecosystem are responsible for providing these benefits.

Three parameters are most responsible for the array of benefits produced by coastal wetlands and estuaries: surface area or extent; water depth, particularly the shallow intertidal or benthic habitat; and water quality. These parameters combine in the estuary to offer a unique morphology which maximizes the amount of free energy available to the ecosystem. The broad, shallow, confined nature of an estuary and its wetlands combine to maximize the absorption of sunlight for photosynthesis and heat; and to improve mixing, including the distribution of nutrients and organisms and the flushing of wastes. This energy is of immense importance biologically, as it allows the organisms to use more of their own energy for growth and reproduction, and less for simple maintenance. In a similar fashion, polluted water imposes a stress on organisms, diverting energy from growth and reproduction for the purpose of maintenance -- relieving the stress.

Incidentally, this free energy is also one of the reasons that the coast is so attractive to man: it conveniently provides or reduces man's requirements for energy for cooling processes, for waste disposal, for transportation, for food production, or for climate modification. Without the energy of the coastal system, man would have to divert more energy -- and more dollars -- to provide these services.

The loss of surface area (by filling), the loss of shallow intertidal benthic habitat (by either filling or dredging), and the loss of water quality are the three greatest adverse impacts in the estuarine ecosystem. As a minimum, mitigation efforts should be designed to maintain -- to compensate for or restore -- these three parameters. Recognition of this need leads to several other guidelines.

* Do not allow a net reduction in the surface area of the estuary and wetland system. If a project causes a loss of surface area, the mitigation effort must add new area to the estuary. Not that compensating for the loss of 100 acres of marsh or mangrove by planting new marshes or mangroves on a tidal mudflat or sandbar is not appropriate mitigation. It would allow a net loss of surface area, and is only substitution, not compensation.

* Do not allow a reduction in the tidal prism, that is, the volume of water exchanged each tidal cycle. Maintenance of tidal prism is necessary to maintain flushing and nutrient exchange.

* Design the mitigation on an ecosystem basis. Restore or replace the ecosystem, not a species or group of species. Thus, you cannot mitigate the loss of intertidal wetlands by the addition of a salmon hatchery. The mitigation project should attempt to retain the same ratio of habitats as those lost in the project being mitigated.

* Be wary of single purpose "enhancement" projects. There is a strong temptation to mitigate by always planting sea grasses, or salt marshes, or mangroves. Maximization of one part of the ecosystem, with loss of the others, ignores the ecosystem concept and will fail to maintain all the benefits of the estuary.

* Utilize the natural energy of the ecosystem. Be wary of the heavily engineered, technological solution. If the project is correctly designed, tides, currents and natural seeding will establish the desired systems much more effectively than expensive hand or mechanical planting.

* Finally, follow up the mitigation effort with long-term research to evaluate the effectiveness of the effort, and to improve the selection and design of future mitigation projects.

In conclusion, let me make an observation about the difference between mitigation in coastal zone wetlands and estuaries and that in inland wetlands, streams and rivers. First, the typical impacts are different; in coastal waters the greatest impacts result from dredge and fill, while in inland areas they are the result of dams and diversion projects. Second, the opportunities for mitigation are usually greater in estuarine areas. In estuaries, seldom is there a totally debilitating impact on the entire system as might be caused, for example, by a dam across a stream. Thus, there remain more alternatives and opportunities for mitigation.

Finally, the legal basis for mitigation in coastal areas is greater than in inland areas. Mitigation in inland wetlands is based upon statutory provisions found in the Fish and Wildlife Coordination Act, the National Environmental Policy Act, and the Clean Water Act. While these laws apply as well to coastal areas, the strongest basis for mitigation there lies in the public trust doctrine. In simple terms, this doctrine, founded in common law, asserts the public's right to unimpaired use of tidal waters for navigation, for fish and wildlife production, and for recreation. The public trust doctrine thus provides the ability as well as the obligation to be more rigorous in our mitigation efforts in coastal wetlands.

An Evaluation of the Ecological Basis of Mitigation Requirements in Oregon Statewide Estuarine Resources Planning[1]

J. J. Gonor[2]

Abstract.--The basis for estuarine mitigation actions is evaluated from the ecosystem viewpoint. Definition and application of the concept of similar biological potential is discussed. Creation and restoration options and their priority are evaluated and a third, alteration, suggested. The importance to mitigation of macrophyte production at all tide levels is emphasized. Methods for predicting the outcome, determining areal equivalences and evaluating adequacy of mitigation are suggested.

INTRODUCTION

The Oregon Mitigation Requirement

The Oregon Land Conservation and Development Commission, the state's designated coastal zone management agency, adopted in 1977 a mandatory statewide planning goal for estuarine resources which includes a requirement for mitigation of tideland losses through dredging or filling. The goal requires that comprehensive plans and activities for each estuary shall protect, maintain and where appropriate, restore natural values of Oregon's estuarine ecosystems, including their natural biological productivity, habitat, diversity, unique features and water quality. Dredging, filling or other reduction or degradation of these natural values in intertidal or tidal marsh areas shall be allowed only if adverse impacts are minimized as much as feasible (be mitigated) by creation or restoration of another area of similar biological potential. The stated objective of the mitigation requirement is to ensure that the integrity of the estuarine ecosystem is maintained. The guidelines for implementing the requirement specify technical factors to be used in identifying and assessing mitigation sites. Indirect effects are not addressed.

This paper is a critical assessment of the ecological basis for the original mitigation provisions in the Oregon estuarine planning goal and its guidelines as adopted in January, 1977. This analysis should be useful in formulating estuarine mitigation requirements in other states because the ecological problems encountered will be similar. This assessment is based on a case study of the first development in an Oregon estuary to be affected by mitigation requirements, the details of which will be published elsewhere.

The Ecosystem Concept Underlying the Oregon Estuarine Goal

Mitigation as a management tool for protecting estuarine natural resources in Oregon has its scientific basis within the ecosystem concept upon which the Oregon estuarine resources planning goal is itself based. This is clear from the emphasis placed upon ecosystem features in the goal text, and the statement that the objective of mitigation is to ensure that estuarine ecosystem integrity is maintained. Technical standards and priorities given in the guideline for achieving mitigation should then be evaluated by application of the ecosystem concept as a framework for fitting human activities into a natural system.

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[1] Paper presented at the Mitigation Symposium Fort Collins, Colorado, July 16-20, 1979.

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This viewpoint has the advantages of identifying major processes and components of the system for examination, simplifying the enormous natural complexity. A disadvantage of this approach is that the identity of component species is minimized as are some processes and changes, both of which may be considered of importance to man by other criteria.

In application to mitigation for adverse effects of tideland alteration, ecosystem values would be given emphasis, and the area to be altered evaluated primarily for its relation to the rest of the system. The goal requirement that unique natural values also be protected would prevent the degradation of diversity within the system by nonreplacement of species or other natural features of the site which are not of great overall ecosystem importance but valued for other reasons. The goal also repeatedly emphasizes the protection of aspects of estuarine diversity as well as general ecosystem properties, possibly creating a conflict over which policy aspect to give priority in an individual mitigation case.

Similar Biological Potential-problems in definition

Biological potential as used in the Estuarine Goal clearly refers to the capacity of an area to develop the desired ecological characteristics after creation or restoration action is completed. Estimating the potential species composition or the annual primary productivity of the community which will develop in a new intertidal habitat not yet existing would require considerable ecological information about the region of the estuary where the proposed action is to be located. Whether the exact replication of a community or its overall functional roles is to be used as the standard to judge compliance, prediction can best be based on an estimate of the characterisitcs of the biotic community in an existing natural area nearest to the proposed mitigation site. Initially the region for the proposed site could be chosen on the basis of physical conditions which determine habitat characteristics, predicted from examination of the surrounding region. This predicted habitat description could then be matched to an existing natural area where the biological characteristics could be evaluated to predict in turn those likely to develop at the candidate site after alteration. A quantitative estimate of the accuracy range of such a predicted ecological potential could be made. The degree of variation in measurable biological characteristics such as species diversity and composition, biomass, etc., would be determined at a number of nearby sites with the same general physical characteristics. Variation between similar sites would provide a measure of the range within which the same characteristics at the proposed mitigation site could be expected to fall.

It is more difficult to propose a definition of biological similarity. Within the objectives of the goal, this implementation requirement is open to interpretations ranging from similarity only in general ecosystem functions to nearly identical, in-kind replacement of the community lost at the development site. The latter interpretation is enforced by the priority the guidelines give to mitigation actions resulting in the development of a flora and fauna both qualitatively and quantitatively similar to that lost. With these criteria, similarity is equivalent to near identity. Objective techniques are available for measuring the degree of similarity of many features of existing communities, but predictions of the detailed features which will appear in a community on a new habitat cannot be done so objectively.

The best predictions can be made for mitigation sites very near the site to be lost by development. Nearby, in-kind mitigation has the fewest built-in assumptions, requires little detailed biological information about the development site and no specific information on the ecosystem role of the community to be lost. Fewest changes of prediction error or wrong emphasis are present. Proximate areas are the most likely to be capable of developing into the same habitat type as that at the altered site, occupied in time by a nearly identical community, with the same relation to the rest of the estuarine system. Inadequate development site analysis will not lead to mistakes in mitigation site selection.

Prescribing an in-kind mitigation action at a site removed from the development site with a reasonable assurance of the outcome requires an adequate development site assessment, and similar assessments near candidate mitigation sites to attempt to most closely match the development site. All features of diversity value as well as those with significant ecosystem effects must be known. Limits of knowledge, bias, insufficiently detailed or careful assessment and temporal insufficiency of the evaluation study may all contribute to missing some important features.

Other related difficulties arise with the formal statement of the mitigation requirement in the Oregon estuarine planning goal. Written in the singular, it implies that all development sites will be homogenous enough so that all of their significant ecological features could be adequately created or restored at a single mitigation site. Estuarine tidelands are diverse; several distinctive habitats may be found from the highest to lowest tidal levels within one area. Larger dredge or fill sites, where mitigation for losses will be important, are unlikely to be uniform physically or ecologically. It will be virtually impossible to create or restore another site with the same mixture of conditions in the same amounts. The requirement could be made more realistic by modifying it to require that the important ecological features of the development site be identified, and recreated elsewhere within the estuary separately or together wherever areas suitable for particular features can be found.

The Oregon mitigation requirement statement also assumes that the present biological features of specific estuarine sites are invariant in time and in their roles and relations to the rest of the system. This is probably the basis for the highest priority given in the guideline to exact, in-kind replacement. However, temporal instability and functional adjustments to slow change are probably more characteristic of estuaries than long term stability. Unfortunately, this type of variation in time is poorly known and it is impossible to determine from short-term site assessment if the conditions found represent peak or low extremes in variability, or are more representative of the long term average conditions. Emphasis on detailed replication of development site conditions appears unjustified scientifically, especially since if such replication is achieved, the same type of variation over time would be expected to change the initial conditions at the mitigation site.

In estuaries where considerable development has already taken place in the past and presumably in the future, the present mixture of areas of different intertidal habitats is not the original state but partly the unplanned consequence of this development. Maintaining this present mixture and distribution of area by giving first priority in mitigation to replacement of dredged or filled tidelands with similar areas may maintain less habitat diversity, productivity or proportion of some desirable natural resource than is possible within the estuarine system. A proposed development site may already be in a degraded state or in a natural state not of high priority value in natural resource management plans. The scope for permissable mitigation actions could be widened by providing an exception to the priority given in the guideline to replacement by closely similar areas when it could be shown that restoration or creation of a different type of habitat would have significant ecosystem advantages or advance a specific objective of management plans. Acceptable mitigation alternatives would then include actions where the creation or restoration involved did not necessarily replace either the type of resources lost at the project site nor some resources once abundant in the estuary.

Similar biological potential would be easier to define for purposes of specifying mitigation requirements if the principal ecosystem features were given emphasis in evaluation of the features of a development site to be replaced through mitigation. Rather than emphasizing identical biological replacement, ecological rates and functions could be emphasized, as well as the relationships to the rest of the estuarine system. The features to be replaced would be the functional roles which community components play, such as the total annual plant production of an area, rather than only the identity and abundance of plant species.

Ecological Productivity Considerations in Estuarine Mitigation

The estuarine goal planning statement specifically mentions natural biological productivity, clearly an ecosystem feature and one which can be estimated and used in comparing the biological potential of sites. Both primary and secondary productivity could be used as measures in determining the amount of area required at a mitigation site for it to be ecologically equivalent to a development site. Of paramount importance for maintaining ecosystem functions is net primary production by estuarine plants, which fixes the amount of energy flowing through the rest of the biotic community. Conservation or increasing this base is important for maintaining the characteristics of estuarine systems.

Tidelands have special features of primary production which, because of their importance to the total system, should receive special consideration in mitigating for tideland losses. Tidelands usually are of large extent and comprise a significant portion of both the bottom surface area and of the high tide water surface area of the estuary. When flooded, tidal areas are shallow enough for light to penetrate to the bottom and support benthic plant production. Intertidal areas can supply a greater proportion of net primary production than equal areas of open water in the estuary. Light reception for photosynthesis is limited by available surface area, and in tideland areas each unit of surface has dual roles in primary production, supporting both benthic and planktonic plant production. Certainly one of the greatest system effects of filling or dreding any area of tidelands, from the lowest to highest tide level, is the loss to the estuarine food web of its plant production because the per unit area contribution is great at all levels.

The variable depths of water above intertidal areas at high tide supports the same type of phytoplankton production as the upper layers of the open waters of the estuary. Because estuarine water turbidity limits light penetration, at the higher tide states, the total production in the volume of water below each unit of tideland water surface area may equal that below each unit of open water surface, despite total depth differences. In addition, each unit of bottom surface area can also support benthic plants not found in deeper subtidal areas and which have a distinctive role in total estuarine productivity.

Estuarine macrophytes are abundant in the intertidal regions of Oregon estuaries. At the highest tide levels, the slight slope of estuarine tidelands results in relatively large expanses of area above the wide mid-tide level flats. These upper tide levels are occupied by the distinctive salt marsh plant community of salt tolerant wetland plants. Tidal flooding is the link by which the marsh exchanges materials with the rest of the system. Salt marsh plants have a high annual net primary productivity which is mostly stored in the stems and leaves until the annual winter die-back. About half this material has been thought to be transported by winter tides out of the marsh and into the rest of the estuary as detritus. Current work casts doubt that this is the fate of this material, and consequently its importance to the estuary may be insignificant.

At mid-tide levels on Oregon estuarine tide flats, a dense mat of large algae appears seasonally throughout most of the estuary. This mat is mostly composed of a few species of fast growing green algae with a high unit area net production which accumulates as a high biomass. This material is extensively transported off the flats to other areas of the estuary, especially in the fall when it also undergoes a die back as temperature and light levels drop.

At lower tide levels, throughout the estuary except in its low salinity upper regions, dense beds of the sea grass Zostera dominate the surface, with their total standing crop increased by algae attached to the grass blades. Primary productivity of sea grass beds is extremely high, making them one of the most important producers in the estuarine system. Sea grasses also accumulate the annual net production in stems and leaves and after the annual fall decline, all of this becomes available to the rest of the system. Tide flats of very fine mud may not support macroalgal mats or sea grass, but also have an appreciable plant production on the sediment surface in the form of a seasonal diatom surface slick or layer.

Much of the overall estuarine food web is based on detritus derived from macrophytes which are largely confined to tidelands. Major potential sources of estuarine detritus for both intertidal and subtidal communities are the phytoplankton, sea grass beds, macroalgal mats and the salt marsh plant community. There are presently no known differences, except breakdown rates, for the roles played in the trophic dynamics of estuarine food webs by equal amounts of estuarine plant detritus from different plant species. All of the estuarine macrophyte species probably have very similar functions as detrital food sources in the system, and their per unit annual net production is of similar magnitude. In making mitigation decisions, as a first approximation for determining the relative values of areas with unlike macrophytes, the annual net plant detritus output of equal areas of all three estuarine macrophyte types can be taken as equal. Such comparisons may be refined from information on macrophyte annual maximum seasonal standing crop. For the plant types involved, estimates of production rates from similar situations elsewhere may be available for use with standing crop estimates to make closer comparisons.

Priorities in the Oregon Mitigation Guidelines

The guidelines for implementing the Oregon mitigation requirement give preference to providing a mitigation site in proximity to the development site, which has similar ecological characteristics and which will in time develop a biota qualitatively and quantitatively similar to that of the tidelands lost by dredging and filling. Similar productivity and no net change in estuarine surface area is also required.

Under this priority provision, biological similarity after the mitigation area is returned to the estuary would necessarily mean detailed similarity of habitat characteristics such as being located within a region of the estuary with the same hydrographic regime, substrate character, and distribution of bottom surface area with tidal height.

These would be required to provide conditions under which the same community as that at the development site would become established. The guideline does not state, but does imply that, as a principle, if lower priority mitigation actions are used, they should be selected on the basis of conforming as much as possible to first priority characteristics. This consistency would assure that the objective of minimizing overall degradation of the existing conditions of the estuarine system was met as closely as was feasible in each case. It also minimizes the likelihood of removing or reducing a component whose role is not presently known but which is important to the system as a whole. Such critical roles are still being discovered and this strategy does not require that they roles be recognized in time to anticipate the cumulative system effects of a series of alterations.

Conditions at the development site are the criteria for assessing the adequacy of any mitigation proposed under this and the other priority types. A relatively detailed ecological site assessment will be required for both the development site and the region of the proposed mitigation site in order to evaluate the degree to which replacement will be attained. The following types of information are some of the more important needed.

1. Physical description: Area, listed by tidal elevations, sediment types, annual hydrographic regime features and the extent of the variation of all of these features within the vicinity of the site.
2. Biotic Community description: Species present, their abundances and biomass for those most abundant or of special interest, with estimates of seasonal changes. Emphasis should be placed not on exhaustive lists but on characterizing differences with tidal elevation and the extent of biological variation within the region of the site. This estimate of variation should be adequate for use as standards in defining acceptable limits for the qualitative and quantitative similarity to be attained.
3. Ecosystem Function Assessment: the net export of primary and secondary production at the sites should be evaluated so that relations to the rest of the system is understood. Actual measurement may be precluded but macrophyte maximum annual standing crop data and rates known from elsewhere are examples of indirect estimation methods. Others are estimates of the type and quantity of organisms used as food by benthic feeding fishes. The area of bottom surface available for remineralization of plant nutrients is included in the physical description.

The significance of the prohibition on reduction in estuarine surface area is not given in the Oregon planning guideline. Most major estuarine ecosystem features are surface related: plant production, water-atmosphere gas and heat exchange, light reception, nutrient regeneration and total habitat space are all directly proportional to surface area. The total maximum volume of tidally exchangeable waters within the estuary is related both to intertidal surface area and depth over it. Retention of surface area minimizes reduction in tidal flushing capacity, an important property to conserve in estuaries with intensive development. Minimizing surface area reductions during development will clearly buffer the estuarine natural system as a whole from irreversible degradation.

The determination of similar biological potential requires an understanding of natural variation in ecological conditions within the areas of interest both in space and in time. Similarity of different areas can only be judged within some measure of the existing range of variation, within the site being discussed or between sites. Animal species composition and abundance, relative species numbers, biomass of standing crops and production rates all vary both with tidal height and horizontally at any tidal height. These features also vary over different scales of time, seasonally and over the years.

The only defendable standard which can be proposed for use in mitigation decisions for determining ecological similarity are quantitative estimates of the range and prevalence of natural variation. For example, areas could be accepted as ecologically indistinguishable if the quantity of their maximum standing crops of macrophytes were demonstrably different at the time of single surveys, but within 95% of the known range of variation around the average of such crops in areas otherwise similar in tidal height, sediment type, hydrography, etc.. Quantitative criteria for variation could be established for various ecological features selected for importance, and the level of acceptable similarity set as meeting a minimum number of these. This becomes more arbitrary as ecological communities become more different, but it would provide consistent and objectively applied criteria of similarity using available or reasonably attainable data.

The guideline for implementing the Oregon Estuarine planning goal gives second priority, when selecting a mitigation area to sites located elsewhere in the estuary, not in proximity to the development site. Such sites are to be selected on the basis of being most similar to the development site in a set of physical characteristics of ranked importance. The similarities would necessarily be between the region of the estuary where the development area is located and that region where the mitigation area would be created or restored but is not yet in existence.

Ecological factors act in concert to limit the distribution and abundance of organisms and the same set of factors may have different relative importances for the same organisms, depending upon which factors are nearest their limiting condition at different times and places. Consequently, listing single physical factors in priority of importance as in the guideline is not very realistic.

In practice, physical characteristics could be most useful not in locating the mitigation site itself but the appropriate region within the estuary for finding such a site. Within this region, unaltered tidelands near candidate mitigation sites could be assessed biologically to determine their degree of ecological similarity to the development site. A final choice would then be made among the available candidate sites on the basis of the greatest similarity of adjacent areas to the development site. Criteria for ecological similarity could be quantitative measures of species diversity, similarity of community species composition, maximum standing crop of biomass and measures of macrophyte production.

Considering the degree of presently unpredictable ecological variation in estuarine tidelands in time and space and the limitations of feasibility, it is not clear how the long term ecological results of the use of first and second priority type mitigation sites would differ significantly. A single set of ecological specifications or standards for the identification and assessment of mitigation sites where natural resource features lost through dredging and filling could be substantially restored or created is given below.

A. Tideland mitigation sites shall be selected for their potential to develop the following biological features as close to the existing state of those at the development site as is possible to attain in practice, in aggregate at one or more mitigation sites:
    1. A qualitatively and quantitatively similar fauna and flora, within the known range of natural variation for that specific habitat type or community within the estuary, and having
    2. Similar ecological relations with the rest of the estuarine ecosystem, such as net export of plant detritus, plant production or provision of benthic feeding resources for mobile predators at high tide.

B. Sites for mitigation are to be sought in a region of the estuary where the following habitat characteristics are most similar to those at the development site so that the characteristics of the biotic community which will develop shall be similar.
    a. Annual salinity and temperature regime of the overlying waters at high tide,
    b. Slope, quantitative distribution of intertidal area at different tidal heights and tidal exposure characteristics,
    c. Substrate type and qualities, e.g., for sedimentary substrates, grain size distribution, organic content and other quantifiable features.
    d. Current velocity and pattern over the area at high tide.

Third priority is assigned to mitigation through restoration to the estuary of areas (by inference, habitats) and resources (by inference both biological and physical) made scarce by past removals, and not necessarily having the same ecological qualities as those lost at the development site. This option recognizes the different but important functio provided to the system by different habitat types and their communities and provides a method for preserving and enhancing the ecological diversity within estuaries. It is not possible presently to evaluate the exact effect of the relative quantities of the estuary occupied by the various habitat types. Restoration aids in avoiding or reversing trends toward system degradation which may not be apparent or ultimately reversible when they reach sufficient magnitude to become apparent. For many estuarine situations this may be the only feasible mitigation option available which meets the Oregon requirement that a mitigation area be either created or restored to the estuary.

Provision of this option and the requirement for restoration made elsewhere in the goal imply that returning an area to the estuary once withdrawn for one use may be a condition for withdrawal of another for a development use now considered of greater priority by economic or societal standards. This forms a link between ecological considerations in restoration and mitigation and the other aspects of land use planning. It shifts cost-benefit considerations from choices between economic and environmental benefits to choices between competing economic uses.

Mitigation by restoration focuses on the main avenues of withdrawl of land from the estuaries in the past: fills of various kinds and diked off salt marsh areas. These have proposed alteration had overall ecosystem benefits which were greater or more important to critical system processes or features than any of those types of actions given priority in the guidelines. Criteria for such exemption might include such features as increasing the available habitat area for macrophyte production to increase the supply of plant detritus to the system, or increasing the area of tidelands in the estuary of habitat types known to support desirable animal communities such as those with abundant benthic species used as food by juvenile or adult fish. Some specific examples of possible beneficial alterations follow.

1. Depth adjustment. The tidal level of areas now higher than in the recent past, because of accelerated sedimentation due to natural or human actions, could be lowered by dredging them down a few feet. A silted-in arm of an estuary now largely at upper tidal levels might be dredged down to mid-tidal levels where a more diverse community could develop. Such a silted-in arm might have a shallow central tidal channel dredged down its length to just subtidal depths and then have the areas to either side sloped toward the channel in a natural way to decrease the total area at higher tidal levels and create more lower tidal areas.

2. Substrate alteration. There are large areas of tidelands within Oregon estuaries where siltation due to accelerated erosion of the watershed after fires or other human activity, has both elevated the height of tidal lands and also changed the substrate to a finer silty or muddy sediment. The flora and fauna of such muds are less diverse and abundant than those of tideflats composed of sandy or muddy sand sediments. A more drastic alteration might be attempted if pollutant free sandy dredge spoils from lower channel maintenance were available. The mud could be dredged out of such areas to lower the bottom level several feet below that ultimately desired. Sandy dredge spoils could then be used to refill these areas to the desired intertidal height and slope. If the salinity regime of the region of the estuary involved was adequate, this type of intertidal habitat reconstruction might include attempts to establish eel grass bed communities by transplanting the grass at the lower tidal levels created by the alteration.

3. Increasing intertidal habitat diversity. The total ecological diversity within the estuary could be increased by alterations which increase the total area present at different tidal heights. Since the biota at different tidal heights differs, a management plan might have as an objective an increase in the area of bottom at tidal heights represented less than others. The slope of intertidal lands is usually not regular and the area of bottom is consequently not equally distributed at different tidal heights. Tidal flats often have very extensive area at mid to upper tidal heights due to earlier natural sedimentary processes at average tidal depths. Alteration of the slope by removal or redistribution of bottom sediment could be used to reallocate the available intertidal area more equally over the tidal height range. This would result in greater areal representation of lower tidal heights and consequently increased ecological diversity at the expense of the quantity of the formerly dominant higher tidal heights.

4. Shoreline adjustment. Redistribution of the possible intertidal habitats within a given amount of intertidal area might be achieved by alterations which emphasized increasing shoreline length. An area might be altered by removal and redistribution of bottom materials so that the upper shoreline length was increased without increasing the overall area of tideland. This could be achieved by excavating the shoreline back in some places and extending it out in others to make the total greater and more sinuous, while controlling slope to maintain the desired height of the upper intertidal region. This method should be an effective way to increase the proportion of area in the unit occupied by upper tidal habitat suitable for establishing a salt marsh community and thus increasing the area devoted to macrophyte production.

5. Redistribution of tidal heights. A wide area of intertidal flat composed mainly of high to mid-tide levels could be made more diverse without increasing total area by excavating shallow channels in it at right angles to the shoreline and placing the excavated materials on a slope to either side of the channels. This could be done in such a way as to mimic natural meandering tidal drainage channels often found on such flats. As a result of such alteration, within the same area there would be proportionately more area represented at both lower and higher tidal levels than before, at the expense of reducing the large area occupied by the habitat at the average height of the flat prior to alteration.

The tideland alteration approach will require the same capability for predicting the consequences of the action as when the creation or restoration methods are used. As in the latter alternatives, alteration may result in unforeseen outcomes or hidden costs because of imperfection of knowledge and understanding. However, withdrawn various amounts of tidal areas from natural production in the several Oregon estuaries. Since the high net production in salt marshes makes them of great unit area importance, their return would be significant. An appropriate measure of the amount to return for mitigating an individual dredging or filling project might be based on the area of tidal marsh required to equal the total net plant production lost at the development site. While the diked area was a part of the estuarine system in the past, it may presently be part of another ecosystem, such as freshwater marsh or pasture land. An evaluation of its total production under its present use compared to its potential production after return to the estuarine system might be one way of assessing the impact of restoration on the estuary. Another would be comparison of the present economic yield of a diked area with that projected for the development whose impact on tidelands is to be mitigated. A comparison of the proportion a diked-off former tidal marsh comprises of total area in its present use within the region of the estuary, with the ratio of present to past abundance of salt marsh would be still another measure of relative importance.

Another advantage to be gained by restoring any former tidelands relates to heating. Estuarine tidal flats have a strong effect on the annual heat budget of estuarine waters and, through temperature effects on biological rate processes, a strong general ecosystem effect. At low tide in summer, the surfaces of intertidal flats and marsh areas exposed by the tide are heated by the sun. When the tide flows back over the flats, the incoming water quickly absorbs this heat and thereby warms. At high tide, the shallow water over tidelands has great surface area and continues to heat by direct irradiance from the sun. In summer, along the Oregon coast, temperatures of incoming tidal waters are anomalously low (near 10°C) because of upwelling effects. In a single tide cycle out-going surface water on the ebb tide can be 5° to 8°C. above flood tide temperatures near the mouth of the bay, even after mixing, due to shallow water-heating.

Because upstream tidal flushing time is appreciably longer than one tidal cycle, the upper ends of Oregon estuaries commonly reach summer peak temperatures of 20°C or more. These temperatures are well within normal tolerance ranges of estuarine organisms and accelerate biological rate processes. This results in increased growth rates in summer and affects other processes such as reproduction in oysters, for example. Natural seasonal heating can then be considered a beneficial effect with respect to ecosystem production.

With the extent of filling and diking in the past, the summer water temperatures of many estuarine systems in Oregon must be lower than they once were. Past submersible land management has resulted in an ecosystem alteration of a very subtle but pervasive and significant extent through changes in the annual temperature regime. This can be reversed through restoration of tidelands during mitigation actions.

Tideland Alteration as a Method of Mitigation

In the Guideline accompanying the Oregon estuarine goal, priority is given to replacing the natural resources lost at the development site as closely as possible, with the alternative of restoring those resources now scarce compared to past abundance if the first priority cannot be met. If sucessfully implemented, these mitigation methods will maintain the natural resource features of the estuary in approximately the same condition they were in at the time the goal went into effect, or altered slightly toward a previous condition.

These methods of mitigation for the adverse effects to the estuarine ecosystem from dredging and filling intertidal lands are not the only possible ones consistent with the natural resource policy objectives of the goal. Placing priority on returning resources similar to those lost or once scarce assumes that the present or former state of the estuarine ecosystem is the most desirable in the future. This may not be true for all estuaries where development will be allowed nor for all parts of them, especially those degraded in the past or for those parts with naturally low values of productivity, diversity or specific habitat features compared to other parts of the same system.

The present form of the Oregon mitigation requirement and priorities appear to preclude using as a mitigation method the alteration of existing tidelands or subtidal areas within the estuary to an intertidal habitat type of greater overall ecosystem value than that lost through development or available from restoration. The objective of using ecological alteration as a mitigation method would be to achieve the required maintenance and protection of tideland biological productivity and natural resource habitat diversity through an active and manipulative enhancement approach.

A process for exception to the existing guideline priorities for mitigation methods could be established to permit such alteration when it could be shown that the unlike dredging or filling tidelands which result in permanent losses, all types of mitigation, whether creation, restoration, or alteration, involve only attempts at changing tidelands. Whether or not the outcome is exactly as predicted before the action, they do not necessarily result in permanent net tideland habitat loss. Like the other methods, alteration would involve manipulation of bottom materials during habitat creation and may cause temporary disturbance to the rest of the system by producing a transient increase in suspended sediment during the operation. Some changes in current flow characteristics in the immediate area will also be expected for any mitigation action which significantly changes intertidal topography. A self-adjusting feature of the estuarine system will tend to buffer alterations which may be too extreme. Tidal flow currents over tidelands affect slope and sediment characteristics and any topographic changes which are strongly deviant from the spectrum of natural conditions will in time tend to be altered by these natural forces to a more stable state.

The greatest objection to alteration as the sole method used to mitigate the diverse losses at a dredging or filling site is that the alteration and the losses combined do not conserve estuarine area but would result in a net reduction. This might be offset by a net gain in surface area elsewhere by another means or by the net gains of desirable features from the alteration despite surface loss.

Approximating Areal and Ecological Equivalencies in Mitigation

Inclusion of restoration options in planning for mitigation is easiest because areas physically removed can be readily identified. Locating other types of areas which are roughly equivalent but not identical to potential development sites is more difficult because of the difficulty of selecting criteria for doing so. There are many methods for comparison and relative assessment of different ecological features available, but no method except the general estimation of energy flow permits different ecological community types to be equated, and it is too insensitive to detail and qualitative considerations to have general use in mitigation. Within an estuary, approximately equivalent areas may be located by the strategy already suggested for locating regions similar to those designated for development. As natural resource data becomes available the capability for identifying similarities will increase.

An interim approach is required for making approximations of areal equivalency for mitigation planning necessary before resource inventory data is available. A listing of general features which can be easily quantified and then used together to roughly determine equivalencies follows.

1. Macrophyte abundance and areal extent of the site supporting different types of macrophytes.
2. Extent of mid-tidal flats supporting small detritivore species used as food by juvenile fishes (critical juvenile habitat area).
3. The distribution of area within the sites at different tidal height.
4. Determining the areas of different tideland sites required to equate the maximum tidal volumes over the areas being compared.
5. Determining the area of unlike sites required to equalize them by the area-submergence time method described below as a crude way of equalizing overall ecological values of tidelands of different type.

An Area-submergence Time Method for Equalizing Unlike Areas in Tideland Mitigation

Restoration of any area to tidal influence will probably result in both direct biological enhancement of the adjacent estuarine area and indirect biological enhancement of a larger area through its effects on estuarine heating. One benefit which might be derived from providing new tidelands of a different type and elevation as compensation for removal of another type would be the general ecosystem effect of added water surface for summer heating. When the more desirable procedure of providing adjacent direct in-kind mitigation is not possible, provision of additional tideland anywhere in the system through restoration might be accepted as a desirable alternative.

Since it is likely that areas offered for intertidal mitigation will not only differ in their biological community and substrate but also in their tidal height, a method for determining the relative value of each area based on a single criterion is required. The method described below requires only survey data on the tidal elevation and area of proposed mitigation sites. It can be used to equalize ecologically different sites areas with different tidal elevation by equalizing their surface area-time submerged relations.

Based on the ecological value of the surface area of tidal waters for light and heat reception, one mitigation procedure would be to restore or create elsewhere a substitute area such that over the course of a year, an equal area covered by water at high tide is present for an equivalent time, depth differences being considered as secondary. For two areas within the same estuary but of different tidal height, time periods of shallow water coverage of the same seasonality will result but of course the depth and duration of the individual episodes of tidal coverage will differ.

The method adjusts equivalent areas at different tidal heights based on the following assumptions:

1. The ecological value of primary and secondary productivity of tidal waters over intertidal lands at high tide is sufficiently high to rank it among the higher priority features sought in mitigation for tideland losses.
2. Providing equal times and water surface area for heat and light reception and heat exchange with the atmosphere are the major features to be equalized between two intertidal areas to secure the above priority benefit.
3. Intertidal heat and light reception has importance for the estuarine ecosystem as a whole because the effect is widely distributed by tidal exchange.
4. The present form of the method assumes the values above are achieved by any equivalent area of tidal water over a wide range of depth and therefore volume differences. This method emphasizes different features from the related tidal prism concept. It does not entirely provide an equal volume over an equal area for an equal time.

The concept of annual acre-days of tidal cover will be introduced by an example. In Oregon estuaries, an area of ten acres of intertidal land of average tidal elevation of +4.5 ft. above MLLW is covered by tidal water of some depth 50% of the time in a year. Such exposure or submergence percentages and seasonal variation in them may be calculated for all levels from tide gauge data with great accuracy and corrections made for amplification of high tides in the upper reaches of estuaries.

In the example, the area provides ten acres of shallow water of variable depth for variable time intervals aggregating to 183 days per year, or it provides 1,830 acre-days of tidal submergence per year. The same annual 1,830 acre-days submergence can be obtained from a different number of acres of tideland at a tidal elevation of six feet, which is exposed 70% of the time and consequently submerged 30% of the time, or 110 days per year. An area of 16.6 acres at +6 ft. above MLLW yields the required 1,830 acre-days per year tidal submergence.

A gently sloping intertidal flat can be partitioned into areas of different tidal elevation and the acre-days of submergence summed for the whole area for purposes of calculating a total equivalent elsewhere. In order to get the same annual acre-days submergence over intertidal lands of higher elevations, a correspondingly larger number of acres would be required.

This paper was prepared with financial assistance from the Coastal Zone Management Act of 1972 administered by the Office of Coastal Management, National Oceanic and Atmospheric Administration and the Oregon Department of Land Conservation and Development.

Mitigation in the Oregon Coastal Management Program[1]

Neal L. Coenen[2] and Bob Cortright[3]

Abstract -- This paper discusses Oregon's requirement for mitigation through creation, restoration of estuarine areas to compensate for adverse impacts. Implementation of the requirement has been uncertain due to unclear criteria and procedures for making mitigation decisions. Based on the results of a technical study and administrative and legislative action mitigation should become a more effective tool for protection of estuarine ecosystems in Oregon.

INTRODUCTION

Oregon requires mitigation through compensation of adverse impacts of dredge and fill projects in addition to the traditional approach of minimizing a projects impacts. While the concept of compensation or offsetting impacts has been well received, the state and local governments have encountered technical difficulties in its implementation.

The Oregon Coastal Management Program is part of a broader statewide concern for land use in Oregon. The state land use program began in 1969 with SB 10. Cities and counties were required to prepare plans and zone all lands in the state. This legislation was reformulated in 1973 with the adoption of SB 100. It created the Land Conservation and Development Commission and required the Commission to set Statewide Planning Goals to serve as standards for preparation of local plans. Oregon's program is based on a system where: (1) the state established planning and management standards; (2) all cities and counties develop coordinated land use plans in response to the standards; and (3) the state reviews and acknowledges plans to be in compliance with the standards.

The standards are contained in Statewide Planning Goals and Guidelines. "Goals" are more than just general objectives. Rather, the Goals are legally enforceable in controlling land use actions of local governments and other state agencies. Guidelines on the other hand, are not mandatroy -- only suggested ways to carry out the Goals.

Oregon's federally approved coastal management program consists of the Goals and acknowledged plans; as well as selected state statutes. Four Goals set planning and implementation requirements for management of coastal resources, including estuaries, coastal shorelands, beaches and dunes and ocean resources. Also incorporated into the program was the State's Removal and Fill law passed by the legislature in 1971.

Mitigation requirements of the program are contained in the Estuarine Resources Goal and in the Removal and Fill law. These two components combine planning and permit regulation to form the basic framework for estuarine management in Oregon.

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MITITATION IN THE ESTUARINE RESOURCES GOAL AND FILL AND REMOVAL LAW

The Estuarine Resources Goal sets out an approach for managing development and protection of estuaries. The Goal specifies permissible uses for natural, conservation and development management units to be designated in plans. Management Unit designations must be based on bio-physical characteristics. Natural units must include significant resource areas, such as major tide flats and eel grass beds. Generally, only low intensity uses which preserve resources are allowed. Conservation units will contain tracts of significant resources smaller or of less biological importance than those in natural units. Uses allowed in conservation units are more intensive than those allowed in natural units yet these uses must conserve resources. Development units are to include deep water areas adjacent or in proximity to the shoreline, navigation channels, subtidal areas for in-water disposal of dredged material and areas of minimal biological significance needed for uses requiring alteration of the estuary. Uses in these units are to be navigation, commercial and industrial water dependent uses. Under this scheme, dredging and filling will occur principally in development management units.

Dredging and filling can only occur when need for a fill is shown, alternatives are considered and adverse impacts are minimized. When these activities occur, mitigation of their effects is required.

> "When dredge and fill activities are permitted in intertidal or tidal marsh areas, their effects shall be mitigated by creation or restoration of another area of similar biological potential to ensure that the integrity of the estuarine ecosystem is maintained" (Goal 16, Estuarine Resources, Implementation Requirement 4).

The intent of the Goal is supplemented by Guideline D. Mitigation must provide an area, that with time, will develop a qualitatively and quantitatively similar flora and fauna. Guideline D also contains priorities for selecting mitigation sites. The priorities from highest to lowest are:

(1) areas in general proximity to the dredge or fill site; (2) other areas according to their similarity in characteristics to the site dredged or filled (e.g., salinity regime, tidal exposure, substrate type, etc.) and, (3) areas or resources which are presently in greatest scarcity compared to their past abundance and distribution.

The mitigation requirement is applied to individual projects by the Division of State Lands when it reviews Removal and Fill permits. Although the Removal Fill law does not explicity mention mitigation, state law requires state agencies to comply with Statewide Planning Goals when they take actions affecting land use. The Division uses its discretionary authority to condition permits to require mitigation.

THE NORTH BEND AIRPORT FILL CASE

In 1976, the City of North Bend applied for a permit to fill 32 acres of Coos Bay to extend a runway at the North Bend City Airport. This was the first case where the mitigation requirement was applied. Subsequently, an interagency team was organized to identify and select a mitigation site. This group worked through the Guideline priorities for site selection and finally settled on a third priority (e. g., a diked marsh area in another part of the estuary). As reported by La Roe (1978) the greatest difficulty was in determining how large a site was necessary and appropriate for mitigation. It was eventually determined that 65 to 70 acres of diked marsh would be needed to mitigate the effects of the fill.

Critical to this determination was an area-equating method developed and applied by Dr. Jeff Gonor of Oregon State University. This method relates surface area and time submerged to give a total "submerged time equivalence" for the area to be filled and that to be used for mitigation.

The Division of State Lands permit was appealed to the Oregon Court of Appeals in 1977 and to the Oregon Supreme Court in 1978. The appeal alleged that a fill for an airport runway violated the public trust doctrine. At issue was whether the doctrine allows substantial fills for other than water related uses. The Oregon Supreme Court decided that non-water related fills are allowed if they are for a public use and the benefits outweigh the detriment to the water resources. Mitigation was not an issue in the case. As a result of the extended litigation mitigation has not yet occurred.

MITIGATION CASE STUDY

In February 1978, Dr. Jeff Gonor, through a grant from the Department of Land Conservation and Development (DLCD) began a case study of mitigation for the North Bend Airport fill. The need for this study became apparent during the review of the airport fill permit. Little rigorous scientific data was available for the sites proposed for fill and mitigation. Without adequate data, a comparison of the sites could not be made and the biological potential of the mitigation site could only be estimated.

Accordingly, the objective of the case study was to improve the scientific basis for and predictability of mitigation decisions. This objective was to be achieved by: (1) fully applying the Goal and Guideline requirements for a qualitative and quantitative evaluation of the lost site; and (2) evaluating to what degree the mitigation site would provide mitigation for the estimated losses. (Dr. Gonor's presentation describes this study and its conclusions in detail.)

MITIGATION TASK FORCE

Confusion and uncertainty about how the mitigation requirement was to be interpreted prompted DLCD to organize an interagency technical task force to review the requirement. This started in July 1978.

The fundamental problem was the use of sweeping and technically vague language such as "maintain", "integrity" and "similar biological potential."

The task force found "integrity" difficult to define in a meaningful way. The overall statement of the Goal did suggest, however, what was meant to maintain integrity. That is, to "...protect the estuarine ecosystem, including its natural biological productivity, habitat, diversity, unique features and water quality." The task force felt that the overall language of the Goal could be used in revising the mitigation requirement. This was also combined with an emphasis on the functional characteristics and processes of estuaries to assure a focus on the estuarine ecosystem as a whole rather than individual development sites.

"Similar biological potential" was also difficult to define. Potential could be measured in several ways; total production, production of key species or species diversity. The task force saw difficulties in selecting one or all of these measures and deciding when one would be more appropriate than another. To resolve these problems, the task force elected not to use the terminology in revising the Goal.

The task force eventually developed the following language:

> Adverse impacts to estuarine resources resulting from dredge or fill activities permitted in intertidal or tidal marsh areas shall be mitigated by creation, restoration or enhancement of an estuarine area(s). The objective shall be to improve or maintain the functional characteristics and processes of the estuary, such as its natural biological productivity, habitats and species diversity, unique features and water quality.

A basic administrative problem with the provision was that it required mitigation for every alteration in the intertidal and tidal marsh areas of estuaries no matter how small. The task force has recommended requiring mitigation only for activities which require a removal or fill permit.

The task force also developed a list of actions it recommended be exempt from the mitigation requirement because of their generally minimal impact. These include:

1. Removal or filling of less than 50 cubic yards of material or when a Removal and Fill Permit is not otherwise required;

2. Filling for repair and maintenance of existing functional dikes when there is negligible physical or biological damage to tidal marsh or intertidal areas;

3. Riprap to allow protection of an existing bank line with clean, durable erosion resistent material provided that:

    a. need for riprap protection is demonstrated and that this need cannot be met with natural vegetation; and

    b. no appreciable increase in existing upland occurs.

4. Filling for repair and maintenance of existing roads when there is negligible physical or biological damage to tidal marsh or intertidal areas;

5. Dredging or filling required as part of an estuarine resource creation, restoration or enhancement project agreed to by local, state and federal agencies; and

6. Other proposed projects or activities where the proposed alteration would have negligible physical, biological and water quality impacts.

The task force also suggested changes to the mitigation Guideline. These changes were to address two problems. The first was to distinguish restoration and mitigation. The second was to clearly relate the planning and permit processes and how restoration mitigation could be dealt with in each.

The four "coastal" Goals all strongly encourage restoration of degraded natural resources. Restoration or the act of restoring is defined as:

Revitalizing, returning or replacing original attributes and amenities, such as natural biological productivity, aesthetic and cultural resources, which have been diminished or lost by past alterations, activities or catastrophic events.

In the context of the Estuary Goal, the restoration provision focuses on restoring to estuaries original attributes lost as a result of past alterations, activities or catastorphic events. Restoration actions are to be considered for all estuaries irrispective of possible needs for mitigation.

On the other hand, the mitigation provision requires compensation for the impacts that will result when dredging or filling activities are to be allowed consistent with an acknowledged plan.

The distinction then is between past and projected changes or alterations in the estuary.

Planning for restoration/mitigation will occur in several stages:

1. Estuary habitats, functions and processes which have been diminished or lost will be identified;

2. Biological resources and physical conditions in areas designated for development requiring dredging or filling activities are inventoried;

3. The type and extent of adverse impacts to be mitigated when development occurs are described;

4. Creation, restoration or enhancement actions or projects to offset past and anticipated adverse impacts are located; and

5. A coordinated program to carry out creation, restoration or enhancement actions or projects is developed.

When restoration and mitigation are addressed in the above manner, mitigation decisions in the permit process can be made more expeditiously. The extent of mitigation needed for a given project would be based on consideration of the following factors at the time of permit review.

1. The extent of proposed dredge and/or fill activity in intertidal and marsh areas;

2. The biological productivity and important resource values of the site. (This should be based on a functional and qualitative assessment of existing communities, habitats and resource characteristics);

3. The adverse impacts and the extent to which they can be minimized through modification of project design or reduction in project scope;

4. Identify remaining adverse impacts to be mitigated by carrying out restoration actions identified in the plan; and

5. Specify the amount and nature of mitigation required for the proposed project.

PENDING LEGISLATION

In March 1979, in response to the North Bend Case and concern about workability of the mitigation requirement, the Oregon legislature began to consider amendments to the Removal and Fill law. The legislation (HB 2619) would essentially codify the North Bend Supreme Court (Morse v. Division of State Lands, 285 Or. 197 [1979]) decision and incorporates many of the recommendations of the Mitigation Task Force into the Removal and Fill law.

Nonwater dependent fills would be permitted for public uses where the public need and public benefits of the use outweigh the detriment to water resources. "Mitigation" would be defined as "the creation, restoration or enhancement of an estuarine area to maintain the functional characteristics and processes of the estuary, such as its natural biological productivity, habitats and species diversity, unique features and water quality.' HB 2619 would also include the task force's list of projects exempted from mitigation. While passage appears likely House and Senate versions of the bill differ over whether the Director of the Division of State Lands should be granted more discretion to waive mitigation. The Senate version proposes to allow the director to waive mitigation in any case where he finds there was no "reasonable manner" in which to accomplish mitigation.

Regardless of the outcome on the remaining issue before the legislature, it is clear the Oregon will maintain its requirements for mitigation. The concepts of mitigation and restoration will be employed and should provide effective management tools for estuarine ecosystems in Oregon.

Finally, it is important to note that the concept of compensatory mitigation has recieved strong implicit support from the legislature. Disagreements about mitigation have focused on how mitigation will work, not whether or not it will be required.

The challenges ahead are to develop a better understanding of the ecosystems we propose to manipulate and to forge the institutional relationships and methods for funding mitigation and restoration projects.

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Mitigation of Habitat Losses in the Estuary of the Hudson River: Suggested Goals for Long Term Management[1]

Edward H. Buckley[2]

Abstract.--Habitat creation can be combined with recreational development along the river to foster greater productivity and balance of species among the higher trophic levels. Examples are described. Reasons are given why release of some detrital sewage might be needed to sustain a potentially useful estuarine community off New York City.

INTRODUCTION

The estuary of the Hudson River has been at the center of human activity for a longer period of time than any other estuary in North America. The writer and journalist, Robert Boyle, referring to the entire river, put it this way, "The difficulty--and much of the wonder--about the Hudson is caused by its diversity. The river is all sorts of things. It is trout stream and estuary, water supply and sewer, ship channel and shad river, playground and chamber pot. It is abused, revered, and almost always misunderstood." A decade has passed since Boyle wrote that in his book, "A Natural and Unnatural History of the Hudson," and much has happened, good and bad, but the basic truth of the statement and the dilemma remain.

This conference is assembled to find out how to halt the degradation of our environment. A major influence for the preservation of habitats in the Hudson has been a pugnacious band of Hudson River enthusiasts who assembled under the banner of the Hudson River Fisherman's Association in the mid 1960's. Armed with data collected for the above book (Boyle, 1969), they both initiated and accelerated changes by winning forty-four of forty-six environmental lawsuits, most of which were settled out of court. This group has made many more strong enemies than strong friends, but they continue to play an effective role in the mitigation of habitat losses in the Hudson. Every estuary needs such a group. Equally essential is a political awareness that demands proper treatment of such a magnificent public resource as the Hudson River. This has never been develop for the Hudson, although it started in the lat 1960's under Congressman Ottinger only to fade in the early 1970's when other issues became more prominent.

My purpose is to share with you the gener findings from a biological information base th was obtained in the early 1970's when, for the first time, an estuarine ecosystem was documented in the Hudson. Then I want to relate these findings to land use along the estuary.

ECOLOGICAL ZONATION STUDIES

Throughout the 1960's and well into the 1970's, the Lower Hudson was commonly referred to as a dead river by the press and generally it was believed to be so. Therefore, it made no difference where one located a sewer outlet a power plant, a marina, or a landfill, since the scale of these endeavors did not impede navigation or drainage. Changes in aesthetics visual and otherwise, were considered a natura part of development. However, Boyle and other believed that a functional estuarine ecosystem still existed in the Hudson, and methodically collected estuarine literature to develop and support that opinion. With that background a with financial support from the Rockefeller Foundation, the Boyce Thompson Institute set out to document the spatial and temporal zonation of the estuarine organisms to see if the coincided with those reported in other estuar particularly those of Chesapeake Bay where tw decades of research data had been compiled un comparable climatic conditions.

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Many estuarine organisms were known to exist in the brackish waters of the Hudson (State of New York Conservation Department, 1936; Symposium on Hudson River Ecology, 1966 and 1969; Howells et al., 1970), but evidence of an integrated estuarine ecosystem was lacking.

Our studies were done in 1971, 1972 and 1973. Preliminary work in estuarine marshes and shallows started in 1968. The main data base was obtained in 1972. Methodologies were tested in 1971 and confirmational data were obtained in 1973. Two years were required to process the 1972 data. Submerged and emergent vegetation, algae, benthos, zooplankton, and ichthyoplankton, a total of 450 species and taxa, were documented in "An Atlas of the Biologic Resources of the Hudson Estuary" which was published by the Boyce Thompson Institute (1977). In it, the spatial and temporal distributions of selected species were described.

During 1972, twenty stations in the Hudson River (from Upper Bay of New York Harbor to Poughkeepsie) were sampled at weekly intervals from March to mid August and then bimonthly from mid August through November. The eighty miles encompassed by these stations covered a salinity range of 28‰ to fresh water and a water temperature range of 3°C to 27°C back to 3°C. Five of the twenty stations were located in major shallow regions of the estuary and all stations were intentionally located away from known local environmental perturbations since the objective was to observe a functional ecosystem, not specific areas of environmental stress. Two consecutive days were required to sample the twenty stations. Phytoplankton, macrodetritus, zooplankton and ichthyoplankton were sampled simultaneously. Fifty-five stations on sixteen transects were sampled for benthic organisms in April, June, August and October.

Phytoplankton standing crop was measured (Sirois, 1973; Sirois and Fredrick, 1978) by pigment analysis of chlorophyll a, b and c following modifications of Strickland and Parsons (1968). Quantitative enumeration of algae was done for four of the twenty stations and identifications were made to the genus level, then compared and contrasted with the pigment analyses. Sixty genera of phytoplankton were recognized, ranging from marine to freshwater forms. The rate of primary productivity was determined at the same four stations, based on changes in dissolved oxygen according to the light-dark bottle technique (Gaarder and Gran, 1927) and Winkler titration (azide modification). All light and dark bottles were incubated in a constant light incubator of approximately 2000 ft. candles at the temperature of the estuarine waters. Estimates of primary production were calculated from solar radiation data, light extinction coefficients, and incubator photosynthesis measurements according to the method of Ryther and Yentsch (1957).

Estimates of zooplankton populations and of macrodetritus were obtained from step tows at eight levels (one minute at each level) using a 57 cm plankton net with 200 μm apertures and offset flowmeter to approximate the volume of water sampled (UNESCO, 1968). Over eighty species and taxonomic groups of zooplankters were recognized. Seven species accounted for 96% of the total number caught. Relative abundance and seasonal distributions were determined for thirty of the more abundant taxonomic designations of which nine have been published in abbreviated form (Hopkins, 1977).

Estimates of early developmental stages of estuarine-dependent fish were obtained by step tows (Dovel, 1964) simultaneous with the zooplankton tows using a 113 cm plankton net with 500 μm apertures and offset flowmeter (UNESCO, 1968). Eggs, larvae, and juveniles representing forty-six species of fish were collected. Five species were found to constitute over 98% of the ichthyoplankton (Dovel, 1973), as was found in the estuary of the Patuxent River of Chesapeake Bay using the same methods (Dovel, 1971). Juvenile fish in shallow areas were collected with a 100-foot beach seine and released. Adult fish were collected with a 16-foot semi-balloon otter trawl and released.

ESTUARINE ECOSYSTEM

I am not going to tell you what estuaries are, since many of you are very familiar with them, but I do need to provide a physical and biological setting to make my comments on land use meaningful.

The estuarine ecosystem of the Hudson includes the entire lower Hudson, a reach of 154 miles extending south from the Federal Dam at Troy, N. Y. Tidal flows at Poughkeepsie, N. Y. (mid point in the lower Hudson) are about 300,000 c.f.s. (cubic feet per second), possibly as great as 500,000 c.f.s. (Busby and Darmer, 1970), while at the mouth of the river, tidal currents are about 1,000,000 c.f.s. (Abood and Bourodimos, 1976). The combined freshwater flows (generally 40,000 to 3,000 c.f.s.) from the upper Hudson and Mohawk Rivers at the northern end of the estuary are relatively small when compared with the tidal flows. The greater freshwater inputs occur during spring, while the lesser occur during summer. All other major rivers that flow directly into the

Lower Hudson have been dammed to make reservoirs for the New York City water supply (which now supplies many other communities as well). During the drought years of the mid 1960's, traces of brackish water extended more than eighty miles upriver and contaminated the Poughkeepsie municipal water supply which is obtained from the river. Normally the salinity gradient lies within the lower sixty-mile reach. Occasionally, the salinity gradient is compressed into the lower fifteen-mile reach for a few days in the spring. This requires exceptionally high flows from the Upper Hudson and Mohawk Rivers, combined with overflows from the New York City water supply reservoirs. Flows of this magnitude are short in duration and end abruptly. They are followed by a pronounced salt wedge that stretches rapidly upriver along the bottom of the main channel and reestablishes brackish conditions in the broad, shallow reach that exists 20-40 miles upriver (Tappan Zee and Haverstraw Bay). The narrow, tortuous, irregularly deep portion of the river that extends through the rocky Highlands (40-60 miles upriver) is extremely well-mixed vertically as the powerful tides roll and swirl through that reach. Within the first five miles, all vestiges of vertical stratification are gone. Here the progression of salinity upriver is slow, except for the repetitive tidal excursions which are several miles in length.

Beyond the Highlands is ninety miles of tidal river and navigation channel which is generally fresh water. Shallows and marshes are common in the upper portion of this reach, but many of these areas are restricted by dredge spoils.

The movement patterns and the productivity of the estuarine organisms in the Hudson, as found in the 1972 Boyce Thompson Institute study, were like textbook examples. Many of the species and quantities of phytoplankton (Sirois and Fredrick, 1978), benthos (Ristich, Crandall, and Fortier, 1977), and of zooplankton and ichthyoplankton (Dovel, 1973) were the same or comparable to those found in the best estuaries of Chesapeake Bay where the same "quantitative" methods had been used. Some of the "textbook" estuarine patterns were immediately apparent (before the samples were processed) merely by sequentially lining up the sample bottles for viewing. Such a display in 1972 for governmental agencies, industries and other interested groups led rapidly to a very much larger research program in 1973 and 1974 by Texas Instruments Ecological Services, supported by Consolidated Edison Company and other electric power companies. The Texas Instruments group confirmed our findings, but also expanded the scope of their study to show that the entire tidal freshwater system up to the Troy dam was all part of the estuarine ecosystem.

The center, or focal point, of an estuary is an enriched nutrient zone, or estuarine nutrient trap. For the Hudson, it appears to be centered at salinities of 3 to 15‰, typica of large drowned river estuaries that are partially mixed (Hydroscience, Inc., 1968; Abood, 1974; Abood and Bourodimos, 1976; Boericke and Hogan, 1977). This salinity rang includes the broad, shallow reaches known as Tappan Zee and Haverstraw Bay that together constitute the main estuarine nursery of the Hudson. (Note that a sizeable fish nursery also extends north into shallow Peekskill Bay and on up through the Highlands reach.)

Superimposed on the natural system is a second and more concentrated nutrient zone. It is produced by sewage discharges. Maximum concentrations of these effluents occur betwee Manhattan and New Jersey, with appreciable amounts carried upriver by the salt wedge into the estuarine nutrient trap zone (Quirk, Lawle and Matusky, Engineers, 1970). Our ecosystem data was obtained in 1972 when most sewage discharges were untreated (U.S. Public Health Service, 1965), as were most industrial wastes It was interesting to note the abundance of zooplankters at both nutrient centers, but the zooplankters off Manhattan in particular were having a bonanza. The rate of phytoplankton primary productivity was also good at both locations, but phytoplankton numbers were low off Manhattan. This reduction in phytoplankto numbers was attributed to overgrazing by the large numbers of zooplankters there (Sirois, 1973), rather than by inhibition by toxic substances, as might have been suspected at that time. The river was far from dead, even in o of its most polluted reaches.

LAND USE

George Spinner (1969) published a "Seria Atlas of the Marine Environment, Folio 18, Th wildlife, wetlands and shellfish areas of the Atlantic Coastal Zone." He excluded all of t Hudson River estuary, as well as the Hackensa and Croton River estuaries, which are portion of the Hudson ecosystem. Three implications struck me at the time: first, that the Hudso was no longer a significant estuarine resourc second, that the area had to be written off a completely committed to urban and industrial development; and third, that a functional estuarine ecosystem was neither required by, compatible with, urban and industrial development. My purpose is to indicate that there i a brighter side to all three of these implications. Folio 18 is an accurate portrayal of opinion one decade ago when it was published. It is not being criticized but is used here a a reference to indicate changes in thinking through the 1970's.

During the 1970's, major changes occurred along the Hudson to improve water quality and protect wetlands in that environment. Specialized waste treatment facilities were added by major industries; oil barges stopped discharging ballast water (containing oil) into the estuary; appreciably less oil was discarded into storm drains by garages and homeowners; and landfills and garbage dumps on each of the estuarine marshlands became inactive except for those at Croton Point, operated by Westchester County, and in the tidal Hackensack meadowlands where extensive filling was carried on under the authority of the Hackensack Meadowlands Commission. More recently, municipal sewage treatment has been upgraded, and by the early 1980's all municipal sewage will receive both primary and secondary treatment.

Smaller changes are continually taking place in the river as part of human activity. Every month, the U.S. Army Corps of Engineers approves a variety of projects that involve the estuary. A few of these probably benefit the ecosystem, and many are localized, temporary impacts. However, some are longer lasting changes that appear detrimental, but are within an acceptably small scale. Although the impact of all these approved activities is basically negative from an environmental standpoint, there is no reasonable alternative. To offset this negative trend, compensating changes will be required in the future. A goal for the twenty-first century might be to harness the demand for more riverfront facilities so that new estuarine habitats can be developed simultaneously with the approved construction. In the interim, it will be necessary to learn how to do such things effectively, possibly through environmental development grants that are combined with specific projects approved by the U.S. Army Corps of Engineers. I want to bring attention to two projects that are realistic to consider at this time. They are the management of sewage release at the mouth of the river and the creation of more productive shallows where new recreational areas may develop.

Controlled Sewage Release

The excellent carrying capacity of the Hudson estuary for juvenile fish (Dovel, 1973) is due mainly to the large zooplankton populations in Tappan Zee and Haverstraw Bay (the productive nutrient trap zone of the estuary). In turn, the zooplankton populations there appear to be supported by phytoplankton and also by detrital sewage from the New York City reach that moves upriver in the estuarine salt wedge (Quirk, Lawler and Matusky, Engineers, 1970). This concept is supported by the 1972 zooplankton biomass data for the estuary which indicate that zooplankters in the nutrient trap zone are an extension at lesser concentrations of the larger zooplankton community centered off New York City. The transitions in zooplankton community structure are gradual and integrated, indicating no abrupt changes in their environment or food source. By using published turnover rates for the major species of zooplankters (which may be different from the rates in the Hudson), it can be calculated that phytoplankton in Tappan Zee and Haverstraw Bay are inadequate to sustain the zooplankton populations there. If this is the case, the apparent food deficit would be made up by detrital resources such as New York City sewage.

The magnitude of the sewage influence upon the estuary can be appreciated even more by observing the effect on populations in the lower eighteen miles of the river. Earlier, I mentioned the bonanza for zooplankters (primarily copepods Eurytemora affinis and Acartia tonsa) and the overgrazed state of the phytoplankton off Manhattan (Sirois, 1973). A small scavenger fish, the bay anchovy, which feeds on both sewage and zooplankton, is so abundant here that its young comprise 70% of the total juvenile fish population sampled in the lower eighty miles of the river (Dovel, 1973). An interesting comparison is with the Patuxent estuary where the young of the naked goby constitute 66% of the total juvenile fish population (Dovel, 1971) and where they, along with skilletfish and striped blenny have a symbiotic relationship with oysters. Oysters were a bountiful commercial resource in the lowermost reach of the Hudson in the 1700's and early 1800's (Boyle, 1969). If the Patuxent data are applicable here, then the large populations of oysters in the Hudson must have significantly influenced the biota at that time. The old descriptions of oyster populations (350 square miles of oyster beds in New York harbor and thirty miles up the Hudson, constituting 50% of the world's available supply in 1800) and of waterfowl (particularly during migrations), as documented by Boyle (1969), make one wonder whether their excrement levels were not approaching those of existing human populations. The bounty of the Hudson may have been dependent upon a very large detrital food base for a long time. Benthic organisms are still exceptionally numerous in this lower reach and maintain a surprising diversity. They could be a large food source for bottom feeding fish, particularly as the water quality improves. Where densities of benthos are commonly 10,000 to 80,000 organisms per m^2, it generally reflects high populations of several species, including four abundant polychaetes: Streblospio benedicti, Eteone heteropoda, Polydora websteri, and Scolecolepides viridis; two isopods: Cyathura polita and Edotea triloba; and two bivalves: Mya arenaria and Macoma balthica (Ristich et al., 1977). This is the nature of the teeming life that is at work, at no cost to the taxpayer, utilizing some of the excessive sewage wastes and keeping the uppermost sediments mixed and partially suspended so that they are aerobic.

Although sewage wastes in 1972 were well beyond the assimilative capacities of the biota (Ketchum, 1974), in some ways sewage might be a great overcompensation for the loss of organic detritus from former expanses of tidal marshlands (over fifty square miles) that are now covered or diked (Regional Plan Association, 1968) and other former detrital sources mentioned above. Within limits, sewage discharged into the estuary from Manhattan and adjacent New Jersey may function to sustain the high productivity of the estuary, particularly when the water temperatures are colder and primary productivity is low.

The controlled release of detrital sewage in the New York City area during periods of low water temperatures ought to be investigated for economic as well as ecological reasons. Ocean dumping of sludges will be terminated in 1981 and more expensive disposal on land will be necessary. If, for instance, ten percent of New York City's winter sewage could be released advantageously into the estuary, a sizeable savings would be involved.

It may be relevant to mention that sewage effluents discharged directly into Tappan Zee and Haverstraw Bay can be expected to cause problems unless they are released in the deeper water near the main channel. Effluents that are discharged into shallow water remain close to the shore, oscillating only a mile or so with the tides. They contribute to, or cause, the summer blooms of blue-green algae that occur sporadically in this reach. Such blooms are undesirable at the time when secondary sewage treatment promises to make the water quality excellent for water-contact summer recreation. On a larger scale, the blooms would also degrade the most productive shallow areas of the estuary.

Compensating Recreational Development

Water quality is improving and expectations are high for more boating, swimming, and general enjoyment of the river. Additional marinas and park facilities will be required.

My comments pertain to recreational development in the broad, shallow Tappan Zee and Haverstraw Bay. This is the main fish nursery area for the anadromous species (striped bass, shad, smelt, menhaden) and marine forage species (Atlantic tomcod in early spring, blueback herring in late summer, alewife), as well as resident estuarine species (bay anchovy, white perch, hogchoker). The nursery area also extends northward through the Highlands for another twenty miles, and beyond that are the freshwater tidal nurseries which are frequented by younger herring and by young sturgeon, as determined recently (W.L. Dovel, personal communication).

Food and habitats for juvenile fish are the most significant consideration along Tappan Zee and Haverstraw Bay. Gross primary productivity (GPP) of algae in this reach was calculated to be 150 to 250 grams carbon per m^2 over six months (May-October, 1972) (Sirois and Fredrick, 1978). This is two to three times greater than algal GPP calculated simultaneously for reaches further upriver in the Highlands and beyond. Six-month GPP values of between 150 and 200 gram carbon per m^2 were found along the main channel and exposed shallow areas, while GPP values greater than 200 grams carbon per m^2 were found in protected shallow areas. Zooplankton populations were also greater in the protected shallow areas. Benthic populations vary according to the sediments, although there is a tendency for benthos to be more numerous in the protected shallow areas and in the deeper channel areas (Ristich et al., 1977). Protected shallow areas may also contain submerged aquatic vegetation where juvenile striped bass and shad, as well as many of the less abundant species congregate. Therefore, the addition of protected shallow areas in this reach can be expected to increase the carrying capacity of the nursery and favorably influence the balance among species.

The eastern side of the river in this reach is exposed to storms. Consequently, sections of the east side would benefit most from protection The Washington Irving Boat Club in Tarrytown, New York, is an example of a marina that provide an excellent habitat. It is built in the shape of an L for protection against storms out of the northwest, and the shallow portion next to the shore is left open and unused instead of the common arrangement with the clubhouse extending out from the shoreline. A broad swath of submerged vegetation is now established in these shallows and juvenile fish congregate there, particularly throughout the summer months. At Rockwood Hall just north of Tarrytown there is a very different situation. Demolition rubble was pushed into the river to form a stubby peni sula which protected a small area of shore, and submerged aquatic vegetation became established However, the clump of submerged vegetation remains small and isolated, and has not attracted the density of juvenile fish that are common in areas of one-half acre or more. Size of the protected area and degree of tidal flow through it affect the productivity of these habitats. Breakwaters that do not extend to the river bottom (except for their supports) and floating docks, as used by the Washington Irving Boat Club, contribute to the success of such project by allowing tidal flow to pass through so that no dredging is required. Some boat clubs with completely enclosed breakwaters require regular dredging and routinely remove "weeds." An example of what we don't need is a mile long dock that was built out from the more protected west side of the river at Piermont. Over the course of a century, a small marsh adjacent to it has grown to over 300 acres. Although is is one of the most beautiful and interesting marshes in the estuary, its contribution (e.g., water quality, habitats, detritus) to this portion of the ecosystem seems small compared to that of the same area of productive shallows that formerly existed.

With some experimentation, more effective and efficient designs could be found that would create shallow habitats similar to those lost by filling. Various configurations should be tested with new marinas that are constructed to enhance the environment they use.

Parks and beaches with aesthetic views are always in demand. Frequently, parks are partially or wholly located on fill along the east shore because the railroad follows or creates that shoreline. A great deal of fill is required to separate the desirable portions of the parks from the railroad, and we know that traditional landfills have no place in this reach of the estuary. However, there may be landfill designs that add to estuarine productivity and special habitats. A narrow, island park could be built, connected to the shore by a floating footbridge. There could be swimming on the exposed side of the island, fishing at the ends, and between the island and the east bank of the river, a protected shallows would be formed. The island could be angled to make two or more acres of highly productive shallows containing submerged aquatic plants that give juvenile fish more protection from their predators. In this manner, the space used to provide the additional park facilities might be more than compensated for within the ecosystem. Relatively little fill and only a hundred feet of floating bridge would be required. Trees could be grown on the island. The cost of such a park would be greater, as would its maintenance, but the park would be completely committed to the enjoyment of the river, the observation of its life, and in keeping with its environment. Parking and playing fields would not be on fill. All such plans to create productive shallows would need to include a spacious passage for tidal flow to prevent an accumulation of silt and to provide the transport of food to the protected nursery area.

Riverside walkways extending from points of public access have been recommended. A conventional filling operation has been considered to provide such a walkway along the eastern shore of Tappan Zee where the railroad embankment forms the river edge. A more useful and interesting alternative is a series of very narrow piers that would enhance diversity and productivity in that exposed shallow area. The piers would trap sediments and within a decade would form a variable but continuous beach line adjacent to the railroad embankment. In order to provide a range of habitats and protection, the piers would be irregularly spaced and angled (e.g., 20 piers along a half-mile waterfront), and constructed of boulders to withstand the pressures of winter ice jams. The piers would extend only fifty feet out from shore, a sufficient distance to form a series of moderately productive shallow areas (each small in size, but not isolated like the Rockwood Hall example). After many decades, sediment deposition would probably extend the beach (i.e., the walkway) and the intertidal zone, and reduce the area available for the protected habitats, but the walkway would still be interesting, educational, and of some ecological significance. An area designed to create protected habitats would not be appropriate for swimming although immediately adjacent exposed areas could be used. This project could lead to the evolution of designs and techniques for the development of similar riverfront areas where habitats can be reestablished.

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Man-Induced Modifications in Estuaries of the Northern Gulf of Mexico: Their Impacts on Fishery Resources and Measures of Mitigation[1]

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Abstract.--The commercial and sport fisheries of the Gulf of Mexico are heavily dependent on the estuaries of the northern Gulf coast. A large variety of man-induced modifications in these estuaries are threatening these resources and the quality of the supporting habitat. This report summarizes potential impacts on the habitat and resource for each type of modification and lists mitigative measures which may be taken to offset these impacts.

INTRODUCTION

Both the commerical and sport fisheries of the Gulf of Mexico are heavily dependent on estuaries of the northern Gulf coast. National Marine Fisheries Service landing statistics for 1976 indicate that a volume of about 1,757 million lbs. of fish and shellfish with a value of nearly $390 million were taken from the Gulf of Mexico and northern Gulf estuaries. Of these totals, about 89% of the volume and 92% of the value consisted of species considered to be dependent on estuaries for the completion of part or all of their life histories. Also, it has been estimated that about 70% of the volume entering the sport fishery consists of estuarine-dependent species (Lindall and Saloman, 1977).

Unfortunately, these estuaries are decreasing in quality and area. Many authorities consider estuaries to be among our most endangered habitats. Basically, they have become dumping sites for waste products from domestic and industrial discharges and for agricultural pesticides by way of upland drainages. Estuarine areas have been significantly reduced by fill for residential and industrial sites and by spoil banks. Spoil banks and stream flow reductions have altered salinity regimes and natural current patterns in many estuaries. These impacts are expected to intensify as populations and the industrial potential along the Gulf Coast expand.

IMPACTS AND MITIGATIVE MEASURES

The evaluation of individual man-induced modifications and the formulation of mitigative measures to offset adverse impacts on the estuarine habitat has long been a function of various Federal agencies under the provision of the Fish and Wildlife Coordination Act and other acts which set out the policies and intents of the government with respect to environmental quality. Also, these evaluations, usually cooperative with these acts, is stated or implied in many statutes of the nation's coastal states.

The following narrative outlines the major types of modifications, their basic impact on the estuarine habitat and the fishery resource, and mitigative measures which may be taken to offset real or anticipated impacts. This report represents a modification and expansion of the impacts on the habitat and resource developed by Kutkuhn (1966) and others. The mitigative measures listed represent those which primarily have evolved over a long period within the Southeast Region, National Marine Fisheries Service and its predecessor, the Bureau of Commercial Fisheries, U.S. Department of the Interior in cooperation with other Federal and state agencies.

General Conditions

To reduce basic impacts of modifications on the estuarine habitat, both the constructing organization and appropriate Federal and state agencies should be guided by the following general considerations: 1) the extent of precedent setting and existing or potential cumulative impacts of similar or other developments in the project area; 2) the extent to which the project will directly (e.g., dredging, filling, reducing access) or indirectly (e.g., alteration of circulation and salinity patterns, sediment transport) affect fishery resources; 3) the avoidance of adverse impacts (e.g., piers in lieu of channelization); 4) the reduction of unavoidable impacts by selecting alternative sites; and 5) the extent to which a project requires a waterfront site if dredging and fill are required.

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[1] Paper presented at the Mitigation Symposium; Colorado State University; Ft. Collins, Colorado; July 16-20, 1979.

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Specific Considerations

Change in Basin Configuration

I. Bulkheads and Fill (bayside residential and industrial developments; Gulf Coast, Florida to Texas).

Both Hutton, et al. (1956) and Lindall and Trent (1975) present discussions of the impacts of bulkhead and fill projects on the habitat and fishery resource. Basic impacts on the habitat include general reduction in shore zone and marsh acreage and changes in marsh drainage patterns. Reduced productivity results through destruction of plant and food sources.

Recommended mitigative measures include: 1) except for eroding shorelines, bulkhead structures shall be aligned no further waterward than mean high tide and constructed so that reflective wave action does not destroy adjacent fishery habitat; and 2) sloping (3:1) rip-rap, gabions, or native vegetation shall be used rather than vertical walls where practical.

II. Channelization and Spoil Deposition:
a. Navigation Channels and "Fish Passes" (Intracoastal Waterway, Florida to Texas; Rollover Pass, Texas).

Potential impacts on the habitat include partial deepening of bays, increased exchange between oceanic bay and marsh waters and hence, changes in temperature and salinity patterns; temporary increases in turbidity (Rounsefell, 1964; Reid, 1956, 1957). Decreased marsh productivity due to intrusion of larger amounts of seawater may reduce plant cover and food sources. Increased productivity may result through increased accessibility to previously inaccessible estuarine or marsh areas and deepened areas offer an escape route from sudden cold fronts.

Recommended mitigative measures include: 1) channel alignments shall make maximum use of natural or existing channels to lessen initial and maintenance dredging; 2) alignment shall avoid shellfish beds and areas of submerged and emergent vegetation to the greatest extent possible; 3) access channels be of uniform or gradually deepening depths or no deepe than the parent water body and aligned with prevailing summer winds where possible to insure adequate circulation and flushing; 4) dredging shall be performed in a manner that minimizes turbidity and spread of sediments into wetlands and on schedules that reduce interference with fish and shellfish migration and spawning; and 5) projects should be design so that circulation patterns, salinity regimes and nutrient and aquatic life distributions are not altered.

b. Segmentation by Spoil Banks and by Runways and Rail- and Highway Grades (Gulf Coast Florida to Texas).

Potential impacts on the habitat include decreasing of average bay depths by shoaling due to entrapment of sediments by structures and reduced exchange of fresh and salt water (U.S. Fish and Wildlife Service, 1963, 1964). Nominal effects on productivity occur due to losses of bay bottom acreage; disruption of circulation patterns, and impedence of fish and shrimp movements.

Recommended mitigative measures for runways and rail- and highway grades include: 1) where wetlands cannot be avoided, bridging shall be used rathern than fill and suitable erosion control devices shall be incorporated into the approaches; 2) structures shall be designed to prevent altering current and salinity patterns and shoaling; 3) road improv ment projects in wetland areas shall follow existing causeways and fill areas when possibl and 4) roadways shall be designed to accommoda other utilities, (e.g., cables, transmission lines, etc.) thus avoiding unnecessary wetland alteration.

Even though spoil material is a product of such operations as channel and basin dredgi the impacts of spoil on the habitat and fisher resource are similar to those cited for rail- and highway grades and possible mitigative measures are described here. These include: 1) dredged material should be considered as a potentially usable resource and if suitable, used for beach renewal, construction, sanitary landfill, etc. with provisions made for access and stockpile for later use; 2) non-wetland areas and existing disposal areas shall be used to the fullest extent possible, this may require raising the height of containment embankments to increase the holding capacity of the disposal area and to render the spoil suitable for export and other purposes; 3) retaining dikes shall be shaped and stabalized to lessen erosion and failure and, where possible, position outfalls to empty back into dredged areas; 4) areas containing submergent or wetland vegetation shall not be used for spoil disposal; open or deep water sites shall be considered in lieu of upland sites only after consultation with appropriate state and Federal agencies; 5) toxic and highly organic materials shall be disposed of in impervious upland containment basins, and 6) sidecast by hydraulic dredges shall be used only in areas unsuitable for hopper or pipeline dredges.

c. Ditching or Draining of Marshlands, (Mangrove Swamps, Florida)

Potential impacts on the habitat include lowered water table; significant changes in vegetative cover; and reduced or loss of nutrient materials from wetlands (Bourn and Cottam, 1950). Resource loss is due to decrease in plant cover and food sources and accompanying loss of fish and shellfish nursery acreage.

There are no standard mitigative measures; projects which drain marshlands are considered on a case-by-case basis.

Protective Works

I. Stream-diversion Spillways (Bonnet Carre Spillway, Louisiana)

Basic impacts on the habitat include redistribution of fresh-water discharge and changes in the salinity regime (Viosca, 1938; U.S. Fish and Wildlife Service, 1959). Depending on the species, some areas may have long productivity or increased nursery acreage with increased carrying capacity.

There are no standard mitigative measures; each project is considered on a case-by-case basis.

II. Salt-water Barriers (Calcasieu and Sabine Lake areas, Louisiana and Texas)

Potential impacts on the habitat include impeded exchange of fresh and salt water; altered salinity pattern distribution and partial or complete elimination of bay and marsh areas from use by fish and shellfish. Resource production is reduced through limited reduction of carrying capacity due to partial or complete loss of access of bay and marsh areas to fish and shellfish.

Recommended mitigative measures for marsh impoundments with no tidal exchange: proposals to impound previously unimpounded marshlands are considered unacceptable; those that reimpound previously impounded marshlands are also unacceptable, but are considered on a case-by-case basis. Impoundments with restricted tidal exchange are considered in the same manner.

III. Seawalls, Dikes and Levees; Tide Control Structures (Galveston Seawall, Texas; proposed hurricane protection dikes, Texas coast)

Potential habitat impacts include reduced influx of oceanic water, reduction of tidal benefits, and changes in salinity regimens (U.S. Army Corps of Engineers, 1959; U.S. Fish and Wildlife Service, 1962). Productivity is generally lowered by diminished access to broad estuarine areas by young fish and shellfish.

Recommended mitigative measures which apply to bulkhead and fill projects may apply here in many instances; these projects are analyzed on a case-by-case basis because of the large areas involved in typical proposals.

IV. Upstream Dams and Reservoirs (rivers emptying into the bays of the northern Gulf of Mexico, Florida to Texas)

Potential impacts on the habitat include changes in volume and seasonal distribution of fresh-water inflow, generally increased salinity, increased downstream concentrations of pollutants, and reduced influx of terrigenous nutrients. Productivity is generally reduced due to deterioration of the habitat, a vital link in the survival of estuarine species.

There are no standard mitigative measures. Impoundments on drainages that enter coastal bays are generally unacceptable, each project is analyzed on a case-by-case basis.

Pollution

This discussion is limited to drainage canals and ditches which empty into the bays along the northern Gulf coast. These are often important elements in upland development plans and the effluents often contain a variety of pollutants generally typical of residential areas.

Depending on the nature of the contaminant, effluents from drainage canals and ditches may alter water chemistry in receiving bays and marshes. Superenrichment, depending on the species, could induce suffocation and loss of productivity or result in limited enhancement of productivity. Certain industrial or agricultural contaminants, depending on the concentration and type, could reduce or eliminate the quality and quantity of marsh and bay production.

Recommended mitigative measures include: 1) drainage canals from upland developments shall not extend through marshes (unless subsidence has markedly lowered the developed lands) but terminate at the upward edge of the marsh; a spreader canal along the upland edge of the marsh may be needed to provide sheet flow through the marsh; 2) adequate upland detention ponds could be constructed where no marsh exists; 3) dredged material should be placed on uplands; 4) drainage plans should become a part of a comprehensive flood plain management plan and the developer should consult with appropriate state and Federal agencies to assure that the drainage meets with applicable water quality standards; and 5) mosquito control drainages should be designed not to drain coastal marshes but to prevent water stagnation and provide access for aquatic predators on mosquito larvae.

Mineral Production

I. Oil and Gas Developments (Gulf Coast, Louisiana and Texas)

Longley et al. (1978) presents a detailed analysis of environmental impacts on marsh and bay habitats due to oil and gas developments and presents mitigative measures for each operational phase. Basically, impacts generally include localized pollution and segmentation of marshes and bays by pipelines and channels. Resource productivity is generally reduced due to poorer survival; hinderance to harvest of fish and shellfish is most significant result.

Recommended mitigative measures for coastal marsh developments include: 1) directional drilling should be conducted from existing sites, canals, bayous, deeper bay waters or non-wetlands rather than dredging new channels or constructing board roads (if this is not possible, temporary roads, preferably plank roads, are preferable to canals for access to well sites); 2) road alignments shall use upland or already disturbed marsh areas to the greatest extent possible; 3) fill from borrow pits (if necessary) shall be dredged adjacent to and on alternate sides of the road; 4) all natural streams and passes are to be bridged or culverted to prevent blockage of tidal flow; 5) no hydrocarbons or related substances are to be allowed to flow or be released into marshes; and 6) upon abandonment, all unnecessary equipment shall be removed and the well site, and adjacent work areas, shall be restored to the original condition. In open waters: 1) maximum use of navigable waters should be made for access to drilling sites; 2) structures which interfere with any fishing operations shall be marked; 3) no hydrocarbons, etc. shall be allowed to flow or be released into bay waters; 4) drilling structures are not to be sited on shellfish beds, submerged grass beds, or other environmentally sensitive areas; and 5) all unnecessary equipment shall be removed upon abandonment or termination of production.

II. Extraction of Sand, Gravel, Phosphate and Fossil Shell (Gulf Coast, Florida to Texas)

Potential impacts on the habitat may include localized increases in turbidity and changes in bay circulation patterns. Resource productivity would undergo some localized loss of carrying capacity in the bay because of loss of shelter and feeding areas.

Proposals for extracting sand, gravel, etc. within vegetated wetlands and within 1,500 ft. from shorelines shall be recommended for denial except for obtaining cultch material; other proposals will be considered on a case-by-case basis.

Power-generating Facilities

I. Steam-electric Plants and Other Facilities (Clear Lake and Cedar Bayou generating stations, Galveston Bay, Texas)

Lewis, et al. (1978) present a detailed discussion on impacts and mitigative measures relative to steam-electric plants. This discussion is limited to intake and discharge facilities only. Basically, potential impacts on the habitat include impingement of organisms on intake screen, entrainment of organisms in the heat exchange system or discharge plume, and the release of toxic materials via the discharge water. Resource productivity would decrease through localized loss of carrying capacity in the vicinity of the intake and discharge structures; productivity of certain vegetative species may increase near outfalls of heated effluents.

Recommended mitigative measures include: 1) once-through cooling systems in areas typified by heavy concentrations of fishery organis are unacceptable, such facilities must employ intake and discharge sites in areas of low concentrations on a site-specific basis and incorporate safeguards to insure that cooling tower blow-down pollutants do not have adverse impacts; 2) intakes shall be designed to minimize impingement (if offshore intakes are used, velocity caps producing maximum horizontal currents of 0.5 fps at the screen are recommended); 3) discharge temperatures shall not exceed the low and high thermal tolerance ranges of the major fish and shellfish in the receiving body of water; 4) if cooling ponds for effluents are required, these shall be constructed in upland areas; 5) the use of construction materials which produce toxic substances (e.g., copper) in effluents should be minimized and the use of biocides (e.g., chloride) to prevent fouling should be avoided where possible.

II. Proposed Geothermal Resource Facilities (geo-pressured sediment areas, Louisiana and Texas)

Suter (1978) developed a report on the habitat impacts of terrestrial geothermal resource developments and mitigative measures which may be implemented to offset these impacts. In some instances, some of the impacts and mitigative measures cited may apply to projects in coastal waters. Major impacts may include some loss of habitat due to construction of plant facilities and temporary disturbances to bay and marsh bottoms through installation of pipelines. Fishery resource productivity will be locally reduced at the facility site due to habitat loss; temperature gradients in the vicinity of end-use facilities may alter floral and faunal composition.

Possible mitigative measures which may be recommended include: 1) all geothermal facilities be sited in non-wetland areas and directional drilling be employed to tap the resource; 2) the facilities be designed to withstand the strongest possible hurricane storm surge; and 3) that during construction and operations, no toxic substances be allowed to flow or be released into marshlands or bays.

No criteria have been developed for geothermal resource developments in coastal areas because of the unknown engineering aspects that such projects may entail. Such projects, therefore, will have to be analyzed on a case-by-case basis.

Recreational Facilities (docks and piers, boat ramps and marinas; Gulf Coast, Florida to Texas)

Possible impacts resulting from recreational facilities include localized damage or destruction to submerged or emergent vegetation beds. Reduced productivity may result because of loss of carrying capacity; increased productivity may occur because of habitat diversification.

Mitigation for docks and piers require construction in a way that does not restrict circulation and sunlight; a sufficient length to reach adequate navigational depths without dredging; and being sited in areas devoid of submerged grass beds or shellfish beds. Boat ramps shall be sited in areas devoid of wetland vegetation and adjacent to waters of adequate navigational depth (e.g., near existing marinas and bridge approaches) to avoid dredging. Marinas shall be sited in areas requiring minimal initial and maintenance dredging; shall be designed so tidal flow and currents are not interrupted; shall be located no less than 1,000 ft. from shellfish harvesting areas unless state statutes specify otherwise; shall consist of open dockage extending to deep water in preference to excavation of boat basins (if such basins are required, they are to be dredged in uplands in preference to wetlands and are to be constructed so as not to create a sump resulting in long-term water quality degradation; shall not have designs requiring filling of wetlands or be sited in areas of known high siltation and shoaling rates; and shall have permanent spoil disposal areas established in upland areas for initial and future maintenance dredging.

Public Utility Facilities (Gulf Coast, Florida to Texas)

Major impacts from public utility facilities such as pipelines, cables and transmission lines include temporary localized strip destruction of submergent and emergent vegetation by excavation and fill activities, destruction of shellfish beds, temporary interruption of circulation patterns and damage or loss of certain floral and faunal elements in transmission line maintenance. Resource productivity would undergo losses through lowered carrying capacity in marshes due to vegetative damage or loss; temporary siltation may alter growth patterns of marsh vegetation.

Possible mitigative measures include: 1) use the push-ditch method of installation in lieu of open channels; 2) if dredging is required, all excavation shall be backfilled so match original floor contours in both excavated and spoil areas (spoil is to be temporarily stockpiled in non-continuous banks to permit natural water circulation followed by back filling if spoil interferes with current flow or trawling operations); 3) alignments of new projects shall follow existing rights-of-ways where possible or the least environmentally damaging route avoiding submerged and emergent vegetative areas and shellfish beds; and 4) herbicide use for right-of-way maintenance shall be cleared with the appropriate state and Federal quality agencies.

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Mitigating Oil Spill Damage — Ecologically Responsible Clean-Up Techniques[1]

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Abstract--Effective mitigation requires preplanning experience, ecological input to planning and the event, and a thorough understanding of political and social demands in oil spill clean-up programs. Attention to public safety should receive primary attention before the ecological and social considerations. The clean-up techniques and their results are analyzed.

INTRODUCTION

Oil spills and natural oil seeps received little notice until the spillage from the TORREY CANYON. This showed that both government and the industry were unprepared and had few proven clean-up techniques. Industry responded to the challenge and developed or purchased a host of containment and collection devices. Their clean-up inventory was augmented by sorbants, dispersants, and chemical barriers. At the same time training programs were initiated.

In the years following the TORREY CANYON accident, many techniques were tried. Straw was used to absorb oil, but was itself impossible to collect. Oil-soaked straw washed ashore and was trapped in the rocks from which it was difficult to recover. Sinking agents such as stearated chalk and amine-treated sand have also been successfully used to sink oil. The oil-soaked chalk and sand fell to the bottom and slowly released oil to the overlying waters. The contaminated sediments could contain sufficient quantities of oil to affect the benthic fauna as well as possibly inhibit recruitment of larvae.

In an effort to return to clean, pre-spill conditions, many well-intentioned clean-up teams tried to remove every last trace of oil. It was common to see steam hoses or high-pressure water hoses used for cleaning oil residue from rocks, piling, bulkheads and marshes. If any animals or plants survive the initial oiling, they are killed by such clean-up procedures. It was also common to see high-pressure hoses attached to fire hydrants for washing down the shore. Fresh water was used to clean intertidal and marsh areas with a total disregard for the salinity tolerances of the intertidal plants and animals.

Dispersants were developed to disperse surface oil slicks into the water column in the form of very tiny droplets where, due to turbulence, current action and other processes, increasing dilution would be achieved (Cormack & and Nichols 1977). Early dispersants had very high toxicity (Smith 1969, Perkins 1968, Simpson 1968), and caused severe ecological damage when used on beaches and coastlines, particularly by untrained personnel. Research and development led to new materials up to 1000 x less toxic than their predecessors (Crapp 1971A). These materials proved safe to use at sea, and in trained hands useful at cleaning shores with minimal biological damage (Crapp 1971, Baker and Crapp 1971). The use of these new low toxicity products was, however, limited in some areas as a consequence of the early experiences.

Dispersants are widely used in other countries, notably in Europe (Cowell 1977). It is, however, usually well controlled and only approved materials passing government toxicity and efficiency criteria are permitted (Wilson 1974). In the United Kingdom users require additional permits that granted only to competent, trained operators.

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These materials have been misused in some areas, but recent research, coupled with control of cleaning procedures to conform with pre-spill categorization of protected areas has reduced mistakes. One clear lesson from both spill clean-up experience (Cowell 1969, Cowell and Baker 1969) and research (Baker 1971) is that use of dispersants should be avoided on plant communities such as tidal marshes. Vascular land plants such as salt marsh grasses, sedges, etc. are particularly susceptible to most commercially available dispersant formulations, particularly those based on solvent materials. Toxicity to salt marsh vegetation is a function of concentration (Baker 1971). Application of undiluted dispersants can lead to high plant mortality. Work by Crapp (1971) has demonstrated that, if applied to beaches during rising tides and using sea water hosing to move oil and dispersant mixtures into the water column under skilled supervision, even the older toxic dispersants can clean beaches with minimal ecological damage. In general, however, such beach cleaning is best avoided unless carefully supervised or essential for economic or amenity purposes, e.g., marinas, docks, amenity areas.

The misuses of dispersants are diminishing. In areas where contingency planning is poor and where clean-up teams are poorly trained, unfortunately, they still occur.

Ecologists themselves are frequently indirectly responsible for this misuse. It is our responsibility to communicate our knowledge of oil contamination and clean-up effects and involve ourselves in training clean-up personnel to use sound collection and removal techniques. We also must ensure the safe disposal of collected materials to avoid additional environmental hazard greater than the spill itself. example, oily detritus might be landfilled in an insecure site from which leachate could easily contaminate surface and groundwaters. This could contaminate drinking water supplies.

PLANNING

There is no substitute for coordinated forward planning. In the areas with a high spill probability, the oil companies usually establish oil spill cooperatives. There are more than 100 such groups now in existence around the coasts of the United States.

Most cooperative groups have an inventory of equipment strategically located throughout their area and drills and exercises are conducted. These groups establish communications systems and regularly update emergency plans. Their efforts are strengthened by the participation of other interested groups, the local fire and police departments and the Coast Guard. Biologists are increasingly becoming involved in the planning and response operations of most of these organizations. It is important that liaison between ecologists and clean-up organizations should be increased since many currently practiced techniques are in themselves damaging to the environment (Lundstedt-Siva 1979).

There are now schools which offer training for clean-up and their programmes emphasize environmental protection. The literature available grows both in terms of research, reviews, and advisory documents (API 1971, 1973, 1975, 1977, 1979).

There are materials closely related to oils in their physical, chemical and biological properties; these are transported nationally and internationally. The Chemical Manufacturers Association operates a 24-hour-a-day emergency response system, CHEMTREC. This industry information system provides safety and clean-up instructions for more than 3,000 compounds and 16,000 trade name products and routinely handles more than 1,000 inquiries each month. This system ties into industry volunteers through participating companies and associations to provide immediate advice and on-site support--should it be required. Both the oil spill cooperatives and CHEMTREC programs work in close cooperation with regulatory agencies.

MITIGATION OF DAMAGE

The degree of clean-up and methods used rarely constitute the environmentally optimum choice. In large part, this is due to the strong political and social pressure surrounding an oil spill. The emotions aroused by dead fish and oil-covered birds force local political demand for the quickest and most complete clean-up regardless of its environmental consequences. The demand for total clean-up leads to such radical treatment as the complete bulldozing of oiled saltmarshes, loss of habitat for spawning species, total destruction of the marsh flora and fauna, breakdown of nutrient regime and drainage patterns, followed by loss of substrate stability and rapid erosion of the marsh soil. Normal bacterial decomposition and sedimentation processes would restore the marsh much more quidkly in most cases. In some cases, no action may be the best action.

Marine Environment

Most open water spills should be left to dissipate by the natural processes of dispersion, solution, evaporation and biodegradation, driven by wind, waves, and sun. Oil spreads into slicks and patches which make collection difficult. There are few, if any, booms and skimmers that operate effectively in heavy seas, and the safety of clean-up personnel should be an important consideration in heavy sea states.

If the oil is approaching land, collection and/or dispersion techniques are indicated. Dispersants require application from specially designed or adapted boats or correctly adapted aircraft. The general application rate for solvent-based dispersants is 1:10 to 1:20 for the new concentrate materials. This means a fairly large volume of dispersant is needed and there is a decided logistical advantage for the new concentrated dispersants. Oil slicks at sea do not have a uniform distribution so that many clear areas may be sprayed with dispersant, with consequent waste of material. Even self-mix dispersants require some mixing energy. The Warren Springs breaker boards are the best mixing system we have seen. Boat application of dispersants is best directed from helicopters to guarantee application on slick areas.

Open sea skimmers are effective in small or moderate-size spills in calm waters. Their limitations are sea state and storage capacity for collected oil. There is little or no environmental damage associated with their use.

The most significant effect on living resources occurring from offshore oil spills is the mortality to sea birds (Cowell 1976, Bourne 1968, 1976). To protect breeding birds or offshore groups during roosting or feeding, dispersant application is recognized as effective. Similar tactics can be used to divert oil driven by wind action (2.5-3% of wind speed) away from sensitive fish spawning areas, tourist beaches, etc. In most situations, however, offshore natural weathering will occur (up to 50% in 48 hours for some crude oil) and dispersion of soil into the water column will take place naturally (Cormack and Nichols 1977). When oil spills occur offshore it is often environmentally best to allow these processes to take place without intervention. Natural weathering and dispersion have successfully dealt with such major spills as the Argo Merchant in the U.S.A. and the Ekofisk Brave blowout in the North Sea.

Intertidal Waters

The intertidal zone can be classified into four groups based upon decreasing particle size:

1) rocky shores, 2) pebble and gravel shores, 3) sandy beaches, and 4) mud flats, including salt marshes and mangroves.

All of these can be further subdivided according to their position in the tidal range and biological zonations. Each has different requirements for oil spill clean-up procedures (Lindstedt-Siva 1979, Cowell 1976), but there is insufficient space in this paper for a full analysis.

Rocky Shores

Rocky shores are often found in exposed areas of high wave action. They have communities composed of algae and an associated fauna of snails, barnacles, mussels, anemones, crustacea, etc. These species are generally wide niche and opportunistic, forming a community with high resilience stability. They are rapid colonisers of available space. The interspecific competition within the community leads to a dynamic balance, maintaining a relatively low level of ecological persistence stability. The communities of exposed rocky shores are naturally exposed to a wide range of temperatures and levels of solar radiation. They are tolerant of rapid changes in salinity and have a wide tolerance to environmental stresses. Wave action on most open coasts is the most significant natural factor controlling community structure (Dalby et al. 1978). Exposed shore communities are, therefore, often easily damaged but also have the capability for rapid recovery through planktonic recruitment, species opportunism and successional processes. Exposed rocky shores are generally rapidly cleaned from oil contamination by wave action; for these reasons, they are best left uncleaned.

Where public opinion and political pressures dictate cleaning, a number of techniques are available. Most of them are likely to increase ecological damage rather than to diminish it. Low pressure hosing using ambient waters provides the safest approach. High pressure water jets will force oil into rock crevices, into shingle between rocks and where they exist, also into sandy deposits. In such situations, it may become trapped. On less exposed and sheltered rocky shores, self cleaning is slower or may not occur. Here tarry residues may remain on the rocks for long periods (Straughan and Abbott 1970). These residues, while unsightly, rapidly lose their volatile and soluble components and become virtually nontoxic. They may form a substrate that itself becomes colonized with marine life. Eventually biodegradation and weathering will remove them; such remains, therefore, due to their impermanence may delay the long-term recolonization processes (Straughan 1971 in discussion).

Dispersants have been used to clean rocky shores in Europe, but their successful use requires ecological supervision and skilled operators if ecological impacts are to be minimized (Baker and Crapp 1971, Wardley-Smith 1970). Their use on current knowledge is best avoided. Even dispersant use, however, is preferable to total scrubbing, high-pressure hosing or steam-jet cleaning. Limpets are the primary herbivores on most rocky shores in the USA and Europe (Southward 1964). They, therefore, control the balance of algal development and the dependent fauna (Cowell 1976, Nelson-Smith 1968, Crapp 1971). Even if limpets are the only species killed in an oil spill, major population shifts may occur which lead to ecological disruption that can take up to ten years to recover (Southward and Southward 1978, Jones 1948). Recruitment of most intertidal species is via a planktonic larval phase, and population can be expected to return to normal in a satisfactory manner. Ovovivparous species (e.g., the whelks Nucella spp.) have a life cycle in which the young hatch as miniatures of the adults. Recruitment from outside areas may be impossible or extremely slow. If these and other species with similar reproductive and distribution mechanisms are affected by the spillage, then recovery of this component of the community may be protracted with other consequences due to interspecific competition (Crapp 1971, Southward and Southward 1978).

Sandy Shores

These occur in both sheltered and exposed locations. Where wave action is high, they are usually self cleaning. They are, however, the most publicly used intertidal habitats, being popular for surfing, sunbathing, sport fishing, etc. The greatest clean-up efforts are usually directed towards these amenity beaches since they are of economic importance to tourism, etc. For obvious reasons, ecological considerations often have low priority. Considerably less harm is done to this habitat than almost any other, since wave energy constantly moves the sands. There is a constant cycle of rapid erosion and deposition. The unstable nature results in almost a biological desert with low biomass per unit area. There is very little primary productivity to support a diverse fauna. Most sandy shore species are planktonically recruited.

In more sheltered locations, sand particle size is often smaller and the substrate more stable; here populations may increase and clean-up problems become greater. Heavy mechanical devices such as trucks and tractors can force stranded oil into the sand where it may remain for long periods. Here degradation may be slow, marine life affected or prevented and recruitment patterns disrupted (Levell 1976). Erosion and deposition cycles may occur in more exposed sites resulting in migration of hydrocarbons, secondary pollution events or slow release of volatile components to overlying sediments. Experience from the AMOCO CADIZ incident suggests that the more sheltered sandy shores had lower residual oil levels when left uncleaned than those in which bulldozing or other mechanized treatments were deployed.

It is recommended that for sandy beach cleaning, the offshore use of dispersants and, where possible, containment in oil spill booms should be used to prevent contamination. If the oil reaches the shore, manual labor should be used to shovel the oil/sand layer, use low pressure water hoses, or allow natural weathering. The deployment of heavy equipment should be kept to a minimum.

Gravel and Pebble Shores

Like sandy beaches, gravel beaches are often in high energy areas. Only low pressure water hoses should be used or the area should be allowed to weather naturally. Following the METULA spill, the contaminated gravel beach was not cleaned and an asphalt residue resulted. Because this spill occurred in the Straits of Magellan in an area of low seasonal temperatures and little biological activity relative to temperate and tropical climates, the METULA experience cannot be extrapolated very easily.

It is almost impossible to use most clean-up techniques on pebble and gravel beaches, but the temptation to use high pressure hoses should be resisted since the substrate is very freely drained and oil may be carried deeply into the beach.

Mud Flats

Mud flats of various types present the most difficult clean-up problems. They are by definition composed of fine particles deposited in the most sheltered locations such as in creeks and estuaries (Dyer 1972). They have high biological productivity (Milne and Dunnet 1972, Stewart 1972, Smith 1974). If oil contaminates such sediments it may remain for long periods. (Blumer 1970, Blumer et al. 1970). The most high risk combination of factors occurs when 'light' refined products are spilled in areas of fine silts, especially after storms or when erosion processes create high sediment bed loads in the water column, e.g., the West Falmouth oil spill (Blumer et al 1970). Heavy products and coarse sedients provide the least risk situation. Under both industry and government sponsorship, a great deal of research is being conducted on the fate and effects of oil in sediments (Anderson 1978, Anderson 1979, Lee 1977, Reed et al. 1977, Levell 1976). Methods of preventing sediment contamination are badly understood and the evidence in the literature is conflicting. There is controversy on the role of dispersants, spill booms and other devices. There are some data to suggest that dispersants may prevent oil from becoming trapped in the sediments of sheltered waters. They may facilitate more even distribution of oil and dilution in the water column, and may enhance the ability of tidal flushing processes in the decontamination of estuarine areas. The research is, however, inconclusive and further work is required. Only when the processes involved are understood can we design clean-up strategies that will mitigate effects. It is important to attempt to prevent mud flats in sheltered areas, creeks and estuaries from becoming contaminated.

Mud flats are physically inherently unstable and will not support heavy machinery of conventional design. If clean-up must be attempted, then low pressure water hosing at receding tides provide a useful approach. If sediments do become contaminated, the only options are natural weathering and dredging. Dredging in itself can do enormous ecological damage to benthic communities and the safe disposal of contaminated dredge spoil has numerous associated difficulties.

The best mitigation measure is prevention. Booms should be used to guard these sensitive areas. Since most marine mud flats are tidal, the booms must be tended constantly and adjusted to the water level changes. If this is not done, the oil will not be trapped within the boom and it will contaminate sensitive areas. This has happened in many oil spill clean-up efforts.

Tidal Marshes

Most salt marshes, including mangrove swamps, are extensions of the fine sediment habitat. They are colonized by an assemblage of highly specialized species, largely composed of salt-tolerant vascular land plants notably the grasses such as Spartina species, Puccinellia spp. and rushes (Juncus species). These plants have lipophyllic surfaces that readily adsorb oil (Baker 1971, Cowell 1969, Cowell and Baker 1969). Such communities may, in part, trap oil at their margins thus preventing the contamination of wider areas. The local level of oil pollution may be serious (Baker 1971, Dicks 1976).

Salt marshes are the most susceptible intertidal ecosystems, not only to the effects of oil but also to disturbance of all types. They are particularly susceptible to oil spill clean-up attempts (Baker 1971, Cowell 1977, Lindstedt-Siva 1979). Almost anything that is attempted in the clean-up of oil contaminated marshes is likely to increase rather than reduce the degree of ecological disturbance (Baker and Crapp 1971).

Most salt marsh plants, including mangroves, have an underground network of roots, rhizomes, and pneumatophores below the mud surface. Apart from the areas immediately surrounding these structures, the soils are generally anaerobic. The plants supply oxygen to their underground parts from the leaves (or in the case of mangroves, the pneumatophores). Oiling of these aerial structures disrupts oxygen supplies to the roots (Baker 1971), but physical damage to the roots and rhizomes is likely to be even more disastrous. Walking, bulldozing, using cutting machinery, etc. all cause major physical and biological damage (Lindstedt-Siva 1979). In general, they are best not cleaned at all; Baker (1971), Cowell and Baker (1969), Bender, et al. (1977) have shown that full recovery under these circumstances can be relatively rapid. Baker (1971), however, in a long-term series of experimental oil spillages has shown that repeated pollution leads to progressive deterioration of the marsh ecosystem. Chronic low-level pollution by oil also leads to severe ecosystem failure (Dicks 1976, Baker 1971). If marshes become contaminated and some degree of clean-up is considered necessary for social, economic, or political reasons, then burning in the autumn has led to the most rapid recovery especially in the naturally fired marshes of Louisiana. This practice, however, cannot be recommended for mangroves. Cutting and removal of oily vegetation may be a useful technique, but hand tools should be used and machinery avoided. Even the tramping of the marsh surface by the labor is almost certain to cause severe damage.

Dispersants should, in general, never be used on salt marsh vegetation since most formulations are toxic to the vascular plants. Penetration of the epidermis takes only seconds and no amount of hosing or washing redeems the situation (Baker 1971). Concentration of solvent-based dispersants is directly related to toxicity.

In fighting oil pollution in which intertidal marsh areas are threatened, the primary strategy should be to prevent oil stranding. Where possible, spill booms should be deployed in the approaches, marsh creeks and estuary mouths (Lindstedt-Silva 1979). The use of dispersants even in heavy applications should be seriously considered. These can be deployed with relative biological safety where water levels may be one or two feet deep. Dilution is rapid and concentrations toxic to marsh vegetation are unlikely to be reached (Cormack and Nichols 1979). This use of dispersants is likely to be far less ecologically damaging than any other marsh clean-up.

Estuaries

Estuaries may contain some or all of the intertidal habitats already discussed. Due to tidal flows, they may be especially difficult to boom in a conventional way. There are "closed horizon" methods that are being developed that promise well (Syratt and Richardson 1979, in press). Booms in tidal areas require continual attention to accommodate to changing water levels.

The Freshwater Environment

Far too little research has been directed towards the fate, effects and clean-up of oil spills in freshwater environments. Spill events are reported, but there is little credible literature on dispersant use in freshwater. They are unlikely to act in the same way as in marine situations since pH, ionic exchange and buffering capacities are different. Until appropriate research has been conducted, it is not possible to recommend the use of these materials in freshwater systems. They are possibly of value in large lakes, but extreme caution is advised where water volumes are small, depths shallow and dilution properties doubtful.

Lakes and ponds are suitable for booming and skimming. Adsorbant techniques and sorbents will have a role provided they can be recovered for safe disposal. Oil becoming trapped on emergent vegetation can be dealt with by cutting and subsequent incineration. The best recovery system will be booming, skimming and removal via vacuum truck or "gulley sucker" vehicles.

Rivers and streams vary from small tributaries to major systems. The best approach will be dictated by the current speed. Small streams can be boomed with adsorbent materials contained in "chicken wire". Suitable adsorbents in descending order of efficiency will be mineral wools, polystyrene, peat or straw. In larger rivers marine booms may be useful, but if current speeds exceed 2.5 knots, they should not be deployed at right angles to the flow. They are most efficient angled to divert oil towards pick-up equipment at the water's edge.

Latitude and Season

Both latitude and seasonal patterns and diurnal rhythms can significantly affect the ecological response to oil and clean-up methods (Crapp 1971, Dicks 1976). It is not possible in this short paper to review the literature on this subject. It is, however, essential that contingency plans should recognize that the toxicity of pollutants to species will vary according to tidal cycles, day and night differences in metabolic rates, activity, behavior, and to winter and summer variation Crapp (1971) clearly showed that northern cold water and southern warm water species were stressed in quite opposite ways by temperature variation. These differences in turn produced significant differences in toxicity response. Laboratory generated toxicity data may be useful for ranking materials in a general manner, but inappropriate for ecological prediction without adequate qualifying field observation. Results obtained with one species may not be applicable to others, even within the same genus (Cowell 1974).

DAMAGE ASSESSMENT

It is tempting to measure ecological damage in light of the acute damage at the time of the spill. Dead birds and dead fish are easy to count and are easy for the public to understand. Mortality is not a measure of ecological damage but the public does not understand interspecific competition, fecundity, recruitment and other ecological processes. Larvae are recruited from plankton in the marine and estuarine communities and downstream drift and insects repopulate freshwater systems.

Ecological damage should be a measure of time and area affected for a "normal community" to be supported on the oil contaminated substrate. For instance, the West Falmouth spill had a small area that would not fully support benthic infauna for at least three years. The area is now back to normal and supports a normal benthic community (Michael et al. 1975).

Federal legislation allows assessment for environmental damages under Section 311 of P.L. 92-500, the Clean Water Act. The danger with regulations of this nature is that the Federal mandate exceeds the technology to perform the task. Namely, ecologists can measure changes in a community, but we cannot agree on a definition of damage. To make matters worse, if the SUPERFUND being debated in Congress is passed with environmental damage conditions, industry may be in conflict with regulatory agenices on the choice of clean-up techniques. A Federal official may require a technique or degree of removal which would cause more environmental damage than another technique--or no clean-up at all.

Recommendations

There will be conflicts of interest wherever oil spills have occurred. No clean-up techniques should be used without a full awareness of the logistic options that are available and their ecological consequences. It is the ecologist's role to advise on these consequences. Economic, amenity and other considerations may, in some areas outweigh the ecological evaluation. No action, however, should be taken without the effects on living resources being put into the decisionmaking equation. Priorities for protection should be established prior to the event and contingency plans prepared taking them into account (Lindstedt-Siva 1979). Plans should include maps identifying the resource, its ecological, economic, social and amenity significance on a local, national and international level. Clean-up strategy should include the identification of access roads, safe disposal sites conforming to solid waste disposal legislation, etc.

Appropriate training for clean-up teams is essential. All training should include some basic ecological information with clear explanations of the significance of the areas designated for special protection. It is important that "on-scene commanders", and local managers should have good ecological advice available to them. Periodic review of plans to incorporate latest techniques, and equipment, research findings and advances in ecological thinking are essential for optimal environmental protection. All field response teams should include ecologists.

Ecological damage assessment techniques must be developed. Currently ecologists are unable to define damage in a credible way. The significance of perceived population changes is not understood in terms of long-term recovery, imbalances in system function or productivity. Even the major population changes that occur in response to natural environmental events such as seasons, cyclic systems, etc. are improperly documented. The position is confounded by the lack of precision in field sampling techniques, the lack of statistically valid replication and the poor theoretical basis of many fashionable approaches.

Ecologists need to put their disciplines in order before really definitive evaluation can be made that can withstand peer review and total support. Any approaches that may hold up to initial analysis must, at the same time, be cost effective in both time and staff requirements. Assessments must take into account both spatial and temporal components of system effect and recovery. The current trend towards estimates of mortality without consideration of reproduction and recruitment potential must be abandoned. Until such problems are resolved and validated, financial penalties imposed upon those responsible for causing oil spills have little scientific validity or equity in law.

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Estuarine Habitat Mitigation Planning in the Southeast[1,2]

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Abstract.--Although habitat loss to non-water-dependent projects has declined in recent years due to national recognition of the importance of wetlands, there is still a decided loss of wetlands in the southeastern part of the United States for water-dependent projects such as marinas, petroleum exploration, navigation and mooring facilities. How long we can continue to lose habitat until fish production and the other attributes of wetlands are irreversibly affected is unknown. The only method for stopping this loss is to adopt a program of zero-habitat loss. This can be achieved through mitigation options consisting of preservation, restoration of habitat to its original state, or de novo generation of new habitat.

INTRODUCTION

The critical marine fisheries habitat in the United States comprises riverine, estuarine, nearshore, and continental shelf zones. The particular importance of these critical zones to fisheries productivity in the Southeastern U.S. (North Carolina to Texas) has been documented by a number of recent publications (Smith, Swartz, and Massman 1966; Lauff 1967; Jackson 1969; Douglas and Stroud 1971; Chabreck 1973; and Thayer, Wolfe and Williams 1975). We have chosen to emphasize the estuarine zone because of its importance in fishery production and the many competing uses that are impacting the potential of estuaries to produce fish and shellfish.

Estuaries are vitally important to the commercial and recreational fishing industries in the southeast, because the majority of species sought after spawn over the continental shelf of the Atlantic and Gulf of Mexico, move into the estuaries for growth and development and later are harvested in nearshore or continental shelf waters. These species are commonly referred to as "estuarine-dependent" because they reside in the estuary during some phase of their life cycle, usually the early stage. Examples of typical estuarine-dependent species are shrimp and menhaden, the former being the top value species in the U.S. fishery and the latter being the top poundage species. Estuarine-dependent species make up more than 88% (both by weight and by ex-vessel dollar value) of the total fishery landings in the Southeast Region (Table 1). These same landings contribute more than 30% of the total U.S. landings of all fisheries.

Fortunately, the almost unbridled destruction of wetlands for non-water-dependent purposes (i.e., housing and industrial real estate) witnessed in the 1950's and 60's has been largely curtailed. This curtailment resulted from increasing national recognition of the importance of wetlands as evidenced by passage of numerous state and federal statutes. But, the real challenge is just beginning. There is still a decided loss and alteration of wetlands--particularly in the southeast region of the United States--resulting from water-dependent projects such as marinas, petroleum and other mineral exploration, navigation, and mooring facilities. Because these activities are water-dependent and are of vital importance to the nation's economy (particularly the energy related projects), the regulatory agencies often decide in their favor over wetland loss.

The major question relative to impacts is, how long can we continue to lose habitat without irreversibly affecting fish production and the other attributes of wetlands? In other words (at least from the standpoint of fisheries) what is the

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Ft. Collins, Colorado July 16-20, 1979. Southeast Fisheries Center Contribution No. 79-40B.

[2] Opinions expressed herein are those of the authors and do not necessarily reflect the policies and views of the National Marine Fisheries Service.

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Table 1. Weight and ex-vessel value of 1973 fishery landings of estuarine-dependent species of South Atlantic and Gulf estuaries (from U.S. Dept. of Commerce).

	So. Atlantic		Gulf	
	pounds 10^3	$\$10^3$	pounds 10^3	$\$10^3$
alewives	8,359	226		
bluefish	3,594	375	530	63
croaker	4,445	397	16,609	1,994
drum, black	133	16	1,928	213
drum, red	241	54	4,074	996
eels, common	297	83	--	--
flounders, unclassified	7,707	2,255	1,692	392
herring, thread	3,721	169	953	43
hickory shad	70	4	--	--
mackerel, Spanish	3,276	548	3,457	1,027
menhaden	85,223	3,132	1,073,770	46,046
mojarra	180	19	--	--
mullet, black	3,959	373	30,183	3,202
mullet, silver	197	23	609	81
pigfish	138	11	15	1
sand perch	13	1	--	--
seabass, black	1,067	349	112	18
seatrout, gray	6,431	583	--	--
seatrout, spotted	1,310	444	7,440	2,501
seatrout, white	--	--	2,025	156
shad	685	215	--	--
spot	7,808	1,068	402	28
striped bass	1,758	594	--	--
sturgeon, common	104	24	8	1
white perch	145	22	--	--
crab, blue	31,813	4,182	43,473	5,313
shrimp	24,557	26,630	182,206	171,854
clam, hard	619	446	--	--
clam, sunray venus	--	--	244	33
oysters	1,656	1,114	14,914	9,713
scallops, bay	37	33	53	63
Totals[1]	199,249	43,390	1,387,697	243,738
Total catch of all species in each region	240,164	57,287	1,543,736	266,634
Percent contribution by estuarine organisms	83.0%	75.7%	89.9%	91.4%
Total catch of all species from all of U.S.		4,857 million pounds 937 million dollars		

[1] Totals are slightly higher for 1974 data which is not subdivided by species at this date (Lindall and Saloman, 1977)

quantitative relationship between amount and quality of habitat and fish production? How much, if any, wetland habitat can we afford to lose and still maintain fishery production at today's level? Until proven otherwise, we believe the wisest position is that all existing wetland habitat is necessary to maintain production of fishery resources.

SUMMARY OF IMPACTS TO ESTUARINE HABITATS IN THE SOUTHEAST REGION

Habitat alteration and destruction are directly related to increased human population. As the population of the Southeast Region grows and expands into coastal areas, the demands for fish and shellfish as well as other uses of the riverine, estuarine, and nearshore coastal waters will grow. Unfortunately, degradation of these critical areas, essential for our marine fishery resources, is cumulative.

The major activities that impact environmental gradients in the estuarine zone are:

1. construction and maintenance of navigation channels
2. discharges from wastewater plants and industries (e.g., heavy metals and chlorine)
3. dredge and fill for land use development
4. agricultural runoff (e.g., increased runoff with associated contaminants)
5. ditching, draining, or impounding wetlands
6. oil spills
7. thermal discharges
8. mining, particularly for phosphate, and petroleum exploration
9. entrainment and impingement from electric generating stations
10. dams
11. marinas

While each of these activities can adversely affect fishery production, only a few of the more insidious ones are briefly discussed below.

o Construction and maintenance of navigation channels represent the single largest form of estuarine alteration in the Southeast Region. The amount of channelization by private interests is unknown, but more than 4,400 miles of navigation channels exist, are under construction, or are planned by the U.S. Army Corps of Engineers within estuaries of the Gulf of Mexico alone. An average of 151.5 million cubic yards of sediment are removed each year from existing channels (Lindall and Saloman 1977). The total yearly disposal from federal maintenance dredging in the Southeast Region is 200 million cubic yards. Not only is productive habitat often lost by dredging, but also by desposition of spoil.

o Dredging and filling for the purpose of creating terrestrial area represents a major loss of fishery habitat. Coupled with spoil islands from dredging of navigation channels, over 138,000 acres of Gulf of Mexico estuaries have been filled (Lindall and Saloman 1977). Dredging and filling for residential real estate in Boca Ciega Bay, Florida, resulted in the immediate loss of an estimated 1,100 tons of seagrass, 1,800 tons of invertebrates and 73 tons of fishery products. The loss of commercial and sport fisheries, based on a 1968-dollar value, was estimated at 1.4 million dollars annually (Taylor and Saloman 1968).

o Modification of wetlands by ditching, draining, and impounding not only removes habitat, but reduces the capacity of the environment to moderate extremes of precipitation. These areas are important fisheries habitat and if left unaltered, regulate freshwater inflow to estuarine areas thereby minimizing salinity stress to resident species.

o Pollution resulting from domestic sewage and from intentional or accidental industrial and agricultural discharge reduces the harvestability of fishery organisms. The resource may survive or recover but often becomes unfit for human consumption. Pollutants include pesticides, petroleum, silt, heat, radionuclides, heavy metals, and disease organisms. Health authorities on the Gulf Coast have closed almost 800,000 acres, 10% of available habitat, to harvest of shellfish, particularly oysters, while the figure for Texas is over 21% (Lindall and Saloman 1977). In 1974, nearly 700,000 acreas of estuarine area in North Carolina, or 30% of the total estuarine area, was closed to shellfishing as a result of pollution, while in 1964 only 24,000 acres were closed. The figure for 1977-1978 in North Carolina is down to 442,000 acres or 19% of the total (personal communication, N.C. Div. of Health Services, Shellfish Sanitation). The total for the Southeast Region is 1.5 million acres closed to shellfishing (unpublished data, NMFS, Environmental Assessment Branch, Southeast Region).

o Dredging and filling of marshland for petroleum exploration and production is a major potential threat to the southeast fishery resources. Information available for Louisiana has been recently documented (Craig, Turner and Day 1977). Annually, Louisiana is losing approximately 16.5 square miles of marsh. This has been recognized by Louisiana in their Coastal Resources Program Hearing Draft (1979). According to this document, approximately 25% of the loss can be accounted for as the direct result of petroleum industry dredging. Unpublished Fish and Wildlife Service records show that 397 permits for excavation of Louisiana marshes were granted to oil companies in 1975 with a direct loss of 1,907 acres of marsh; 453 permits in 1976 with a direct loss of 2,424 acres; and, during the first six months of 1977 there were 206 permits with a direct loss of 1,295 acres. Thus, there has been the direct loss of 5,626 acres of Louisiana marsh in 2.5 years just to the petroleum industry.

In addition to these direct impacts, Craig, Turner and Day (1977) documented indirect impacts which result from canal and slip excavation and side-of-canal deposition of spoil. The canals widen from 2 to 14% per year for a doubling time of 5-60 years. Indications also are that in marsh areas where there are numerous man-made canals there is an accelerated deterioration of the surrounding marsh as a probable result of canal side sloughing and interference with normal drainage and sheet-flow patterns. Craig, Turner and Day (1977) relate fishery losses to be directly proportional to wetland loss and estimate that 8 to $17 million of fishery products and services are lost annually as a consequence of present wetland loss in Louisiana.

CONCEPT OF ZERO-HABITAT LOSS THROUGH MITIGATION

As is evident from the foregoing discussion, the present philosophy towards wetlands management in the southeast is one of allowing continued habitat loss, albeit small and seemingly insignificant when considered on a case-by-case basis. We are convinced, however, that this "inevitable-loss" philosophy cannot continue indefinitely because of the cumulative impacts involved. Alternatively, decision makers can and must adopt a philosophy of zero-habitat loss if fishery production and other attributes of wetlands are to be maintained.

Immediate acceptance of such a radical departure from present philosophy cannot be expected. In fact, aside from any socio-economic objections, zero-habitat loss may be impossible to attain within the next decade or so because of our incomplete understanding of ecological systems and, thus, our inability to accurately predict impacts of proposed projects. We are, however, able to identify general principles of impacts associated with various types of projects and we are even beginning to develop a "science of impact minimization" (Darnell 1978). Nevertheless, we are convinced that researchers and administrators alike must look beyond the goal of simply minimizing impact. We must begin thinking in terms of a national goal of zero-habitat loss based on mitigation options consisting of preservation, restoration and generation of habitat.

Mitigation through Preservation

Preservation is an option that perhaps is not recognized by many as representing mitigation. Nevertheless, it is the most effective option available and is often successfully obtained in the Corps of Engineers Section 10 and 404 permitting process. For example, unpublished NMFS

Table 2. Summary of wetland alterations in North Carolina, South Carolina, and Georgia under the Corps of Engineers' permit program, 1978[1]

NORTH CAROLINA

Habitat Type	Proposed for Dredging and Filling	Recommended for Preservation by NMFS[2]	Alterations Permitted by COE[3]
Regularly Flooded Marsh	4.20	3.97	.23
Irregularly Flooded Marsh	29.43	23.59	5.84
Wooded Swamp	335.12	311.70	23.42
Submerged Vegetation	.31	.28	.03
Unvegetated Shallow Water Bottoms	60.76	25.23	35.53
TOTAL	429.82	364.77	65.05

SOUTH CAROLINA

Habitat Type	Proposed for Dredging and Filling	Recommended for Preservation by NMFS	Alterations Permitted by COE
Regularly Flooded Marsh	33.80	29.81	3.99
Irregularly Flooded Marsh	80.88	14.51	66.37
Wooded Swamp	54.04	11.27	42.77
Submerged Vegetation	---	---	---
Unvegetated Shallow Water Bottoms	23.02	.65	22.37
TOTAL	191.74	56.24	135.50

GEORGIA

Habitat Type	Proposed for Dredging and Filling	Recommended for Preservation by NMFS	Alterations Permitted by COE
Regularly Flooded Marsh	131.83	123.49	8.34
Irregularly Flooded Marsh	0	0	0
Wooded Swamp	0	0	0
Submerged Vegetation	0	0	0
Unvegetated Shallow Water Bottoms	6.59	4.01	2.58
TOTAL	138.42	127.50	10.92

[1] Data expressed in acres.

[2] National Marine Fisheries Service.

[3] Corps of Engineers

records show that in 1978, 760 acres of vegetated wetland and shallow-water habitat in coastal North Carolina, South Carolina and Georgia were proposed for dredging or filling for private development (Table 2). Through the efforts of the National Marine Fisheries Service, as well as other state and Federal fish and wildlife agencies, 548.5 acres (72.2%) were spared, either through outright denial of the permits or through identifying less damaging alternatives. This, in effect, represents mitigation through preservation.

Unfortunately, we do not yet have an effective system for collating similar data for the remainder of the states in the southeast region. We hope to within the next few months. The important point is that Section 10 and 404 permit activity in North Carolina, South Carolina and Georgia is less than 25% of that occurring throughout the remainder of the southeast region, and it represents what can be accomplished with mitigation through preservation.

Mitigation through Restoration

The numerous impacted wetlands that exist in the southeast offer an opportunity to restore acre-for-acre any wetland that is lost to future projects. This may be relatively simple, such as restoring tidal flows to a wetland area impounded by an old highway, or more complex such as restoring a dredged cut or spoil disposal area that is no longer required (e.g., oil and gas well canals).

Planning for wetland restoration is complex and subjective because restoration technology is still largely in the development stage. Nevertheless, considerable work is underway or planned that will provide much needed information, as evidenced by Garbisch's (1977) review of marsh establishment experiments nationwide. Excluding projects currently underway by the Corps of Engineers Waterways Experiment Station, Garbisch identified 105 marsh establishment projects completed or underway and 14 that were planned for the immediate future. Of the 105 completed or underway, 68 were on the east coast, 17 on the gulf coast, 8 on the west coast and 12 inland. Based on this review, Garbisch developed practical guidelines for site preparation, marsh establishment, and site management and maintenance. These should be followed and they undoubtedly will be refined as more information is gained.

Restoration of destroyed seagrass beds is also possible and, as with marsh establishment, technology is still evolving. Table 3 summarizes some of the recent work done in North Carolina and Florida. Guidelines are provided in van Breedveld (1975).

We are unaware of any documented attempts to restore non-vegetated wetlands (e.g. tidal flats and other shallow subtidal waters) that have been impacted by dredging and filling (e.g. temporary barge canals for bridge building). Certainly these habitats must also be considered in a program of zero-habitat loss. Fill should be removed at least to an elevation that allows tidal inundation, and consideration should be given to refilling the dredged areas at least to the elevation of the photic zone.

Mitigation through Generation of New Habitat

Our concept of mitigation through generation of new habitat is not synonymous with converting one type of wetland habitat to another. For example, the building of marshes in shallow-water habitats does not represent mitigation in our opinion. Rather, it represents habitat substitution, in this case the substitution of shallow-water habitat (usually tidal mud flats) with marsh habitat.

Contemporary thinking among many planners and wetland managers in the southeast is apparently focusing on what we refer to as the "marsh building kick". If an upland area cannot easily be found to deposit dredged material, or if a public interest project will destroy wetland vegetation, then to mitigate damages (some even claim improvement of habitat) one simply uses the spoil to build a marsh along an existing shoreline or other shallow-water habitat area. Hedgepeth (1978) refers to this activity as the "east coast Spartina syndrome". The notion is that, since marsh is the key to productivity because of detritus production, the best thing to do for an estuarine system is to promote the growth of Spartina. Hedgepeth points out the fallacy of the universal acceptance of this concept. Namely, extensive flats often separate the marsh from the deeper waters of the bay and are a significant component of the productivity and organic cycles in the estuary. As such, secondary productivity from the tidal flats may be more significant than detritus from salt marshes. Thus,

TABLE 3. Summary of seagrass establishment efforts in N. C. and Fla.

SPECIES	LOCALE	PLANTING TECHNIQUE	RESULTS	COMMENTS	SOURCE
Halodule wrightii	Port St. Joe, FL	30 and 60 in.^{2} plugs planted on 3,6, and 9 ft. centers	Good survival	30 or 60 in.^{2} plugs on 3 ft. centers survived best. 60 in.^{2} plugs better tolerate silting	Phillips (1977)
	Tampa Bay and Boca Ciega Bay, FL	plugs taken with post hole digger planted close together	Good survival	Needs aerobic substrate dormant period is best time to transplant	van Breedveld (1975)
	Escambia Bay, FL	plugs planted in late summer at .15m intervals in water .3 to 1.0m deep	Good survival		Rogers and Blisterfeld (1975)
	Back Sound, NC	Shoots woven into 20x20 cm biodegradable paper meshes. Meshes anchored to substrate.	Good survival		Fonseca, et al (in press)
Syringodium filiforme	Tampa Bay and Boca Ciega Bay, FL	plugs taken with post hole digger and planted close together	Excellent survival	Survives well in aerobic or anerobic substrate	van Breedveld (1975)
Zostera marina	Back Sound, NC	shoots woven into 20x20 cm biodegradable paper meshes and anchored to the substrate	Excellent survival		Fonsecca, et al (in press)
Thalassia testudinum	Tampa Bay and Boca Ciega Bay, FL	plugs taken with post hole digger and planted close together	Good survival	requires an aerobic substrate	van Breedveld (1975)
	Biscayne Bay, FL	seeds anchored to substrate	poor survival in high energy areas and good survival in low to moderate energy areas		Thorhaug, Hixon (1975)

creation of marshes in the shallows may actually result in interference with a natural system by accelerating sedimentation and accretion and consequent reduction of the mud flats.

Under a program of zero-habitat loss, generation of new habitat for mitigation purposes would consist of converting upland (non-wetland) habitat to a wetland habitat to replace that which is necessarily destroyed in construction and operation of a water-dependent project. Unfortunately, a sufficient data base does not exist to allow unequivocal selection of the measures necessary to optimize mitigation. Four critical questions that must be answered are:

1. What type of new habitat should be generated?

2. Where should it be located?

3. What size should it be?

4. What configuration should it be?

Answers to these questions will depend largely on the ecological setting of the project area. Initial approaches will be largely intuitive until more definitive answers can be obtained through multidisciplinary research by physical and biological scientists. Meanwhile, we suggest the following basic guidelines:

1. Habitat Type - The habitat generated should be as nearly identical as possible to that destroyed. For example, a Spartina alterniflora marsh should be generated if a Spartina alterniflora marsh is destroyed. The same would apply to mangrove species, submerged grasses and tidal flats. Each should be replaced in kind.

2. Location - The new site should be located as near the destroyed site as possible, preferably adjacent to the project site. In any event, the new site should be in the same estuarine system as that of the destroyed habitat and should not interrupt existing circulation or drainage patterns.

3. Size - the size of the habitat generated should be at least equal to the size of the one destroyed, preferably larger.

4. Configuration - There are many possibilities regarding configuration, depending on the ecological setting. Regardless of the configuration chosen, it should not interfere with existing drainage and circulation patterns in adjacent wetlands.

Despite this lack of information, we believe now is the time to begin requiring, at least on a pilot basis, that permits contain stipulations for habitat generation. Accompanying these stipulations would be the requirement for the construction agency (private or Federal) to fund before and after studies of the ecology of the area, including the impact of the project and the rate of biological recovery, for the express purpose of improving our technology and scientific data base in dealing with future development projects.

SUMMARY AND CONCLUSIONS

Water-dependent projects that are of vital importance to the nation's interest (e.g., petroleum development, navigation and mooring facilities) are causing a decided loss and alteration of habitat when their cumulative impacts are considered. Unless cumulative impacts are recognized and steps are taken to prevent continued loss, the point eventually will be reached when the production of fishery resources is irreversibly reduced. To insure this does not occur, we propose a program of zero-habitat loss through mitigation options consisting of preservation, restoration and generation of habitat.

A program of zero-habitat loss will require long-range and innovative planning and research. For example, with regard to the present rate of 2,000 acres of marshland dredged and filled each year in Louisiana by the petroleum industry, the need for long-range planning is obvious. This rate of loss can be expected to increase under the Nation's energy program. Also, as petroleum resources in Louisiana wetlands are depleted, socio-economic pressures will increase the probability that oil and gas exploration and development activities are expanded into other wetlands in the southeast where production potential exists.

Some mitigation measures that can and must be planned for in regard to the petroleum industry include sharing of existing navigation and pipeline canals; identifying and delineating those petroleum deposits that can be reached by slant drilling from existing canals rather than dredging new canals and slips; dredging joint-use canals where deposits can be reached only by vertical drilling or where access to slant drill sites is required; restoring abandoned canals and slips for every new canal and slip that must be dredged; and creating wetland habitat out of upland habitat to compensate for losses.

Research needs associated with this planning are obvious. Adequate documentation, through quantitative and statistically valid data acquisition and analysis, must be provided if mitigation measures are to be accepted and applied. Simulataneously, and just as important, an adequate follow-up system must be designed and implemented to insure that mitigation measures stipulated in permits are being carried out. To our knowledge, no such follow-up system exists in the southeast region today, either within the regulatory agencies or within the advisory agencies. In our opinion this is a critical weakness in the existing environmental management process and must be corrected if an effective program of zero-habitat loss, or any other kind of mitigation program, is to be successfully implemented.

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Coastal Habitat Mitigation in Tampa Bay, Florida[1]

Roy R. Lewis, III,[2] Carolyn S. Lewis,[3] William K. Fehring,[4] and James A. Rodgers, Jr.[5]

Abstract.--Historical land development practices and harbor development in Tampa Bay have resulted in large scale losses of coastal habitat. Cooperative efforts by citizens and regulators has resulted in successful mitigation of some wetland losses by creation of tidal marshes and moving threatened mangroves onto dredged material islands. Avian nesting habitat has also been created to mitigate beach development.

INTRODUCTION

Tampa Bay is an estuary located on the west coast of Florida (fig. 1). One-sixth of the state's population lives in the three counties bordering its shores. The subtropical climate of the Tampa Bay area supports both tropical mangrove forests and temperate tidal marshes along the shores of the estuary. Lewis (1976) determined that 5,630 ha of these intertidal plant communities remained in the bay. This represents a 44% loss from that present in 1876, when the bay was in a pristine state. Submerged vegetation in the bay consists of five species of seagrasses and 216 species of algae. Over 75% of the seagrass meadows along the Hillsborough County portion of the bay have been lost during this same period (Lewis, unpublished). The major cause of these losses has been dredging for land development and harbor construction (Taylor and Saloman 1968, Simon 1974, Lewis 1976). As a result of the loss of wetland habitat and continued pollution, commercial harvests of marine finfish and shellfish have declined, with a 20% decline between 1965 and 1972 along the west coast of Florida (Lewis 1976).

Recently efforts have been made to create wetlands on dredged material deposits in Tampa Bay (Lewis and Lewis 1977) and manage dredged material islands for optimum utilization of nesting seabirds and wading birds (Lewis and Dunstan 1975, Lewis and Lewis 1977). Recent mitigation efforts involving cooperation among a number of agencies and individuals (e.g. U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Corps of Engineers, National Audubon Society, Tampa Port Authority, and Hillsborough Environmental Coalition) are discussed here.

MITIGATION PROJECTS

The first project involves a proposed docking facility for shrimp boats proposed by the Tampa Port Authority. To accomodate expansion of a local shipyard, the existing shri docks along an abandoned World War II drydock had to be replaced. The only feasible locatio was determined to be the shore of an old fill site created for a road causeway in 1927 and later expanded by disposal from a local flood-control project. The area supports a healthy fringe of black mangroves (*Avicennia germinans* L.) and a productive intertidal area (fig. 2).

The authority started with a plan which would have involved some 5.3 ha of intertidal or subtidal land. The regulatory agencies involved required hectare-for-hectare replacemen of the habitat to be destroyed as mitigation. Due to limited areas for mitigation, 3.3 ha of the project were eliminated until a later date and 2.0 ha of mangrove/marsh habitat scheduled for creation on nearby dredged material island The primary site is a new dredged material island created in February 1978 as part of the Tampa Harbor Deepening Project.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Ft. Collins, Colorado, July 16-20, 1979.

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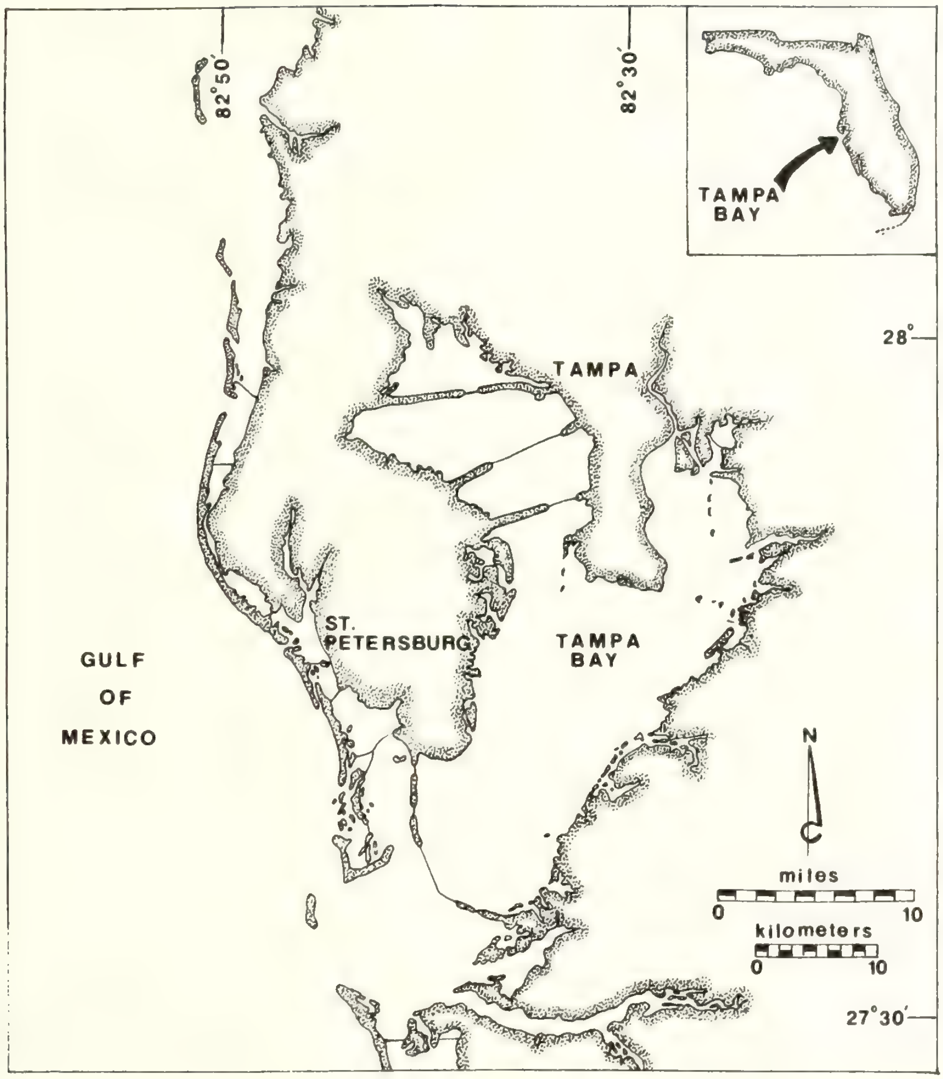

Figure 1.--Tampa Bay, Florida.

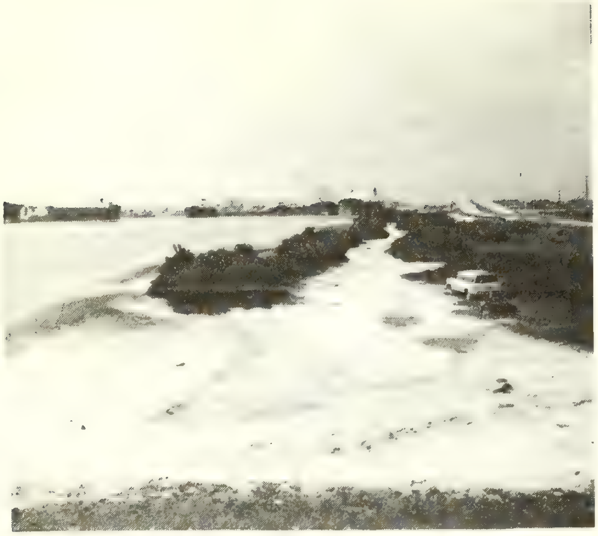

Figure 2.--Area of proposed shrimp dock facility, note mangroves at water's edge.

The habitat areas are being created by first transplanting all available young black mangroves from the proposed project site to the island. Later plugs of cordgrass will be transplanted from nearby marshes. This work is being done by the Young Adults Conservation Corps (YACC) of the Tampa Marine Institute and the environmental staff of the Tampa Port Authority. The first phase of the project involving moving the mangroves was started in January 1979 and to date has moved nearly 1500 plants.

The plants are first pruned to 2/3 of their height (original height 0.5m), dug up with shovels, rootballed with burlap, and transported by boat and planted. The initial set of trees were planted on 2 m centers from +15 cm mhw to -15 cm mhw across a small lagoon. Viability of the transplanted trees appeared initially to be very low. However, 34 of the first 100 trees now show new growth. These were planted above mean high water (mhw). Only five of the second 100, planted below mean high water, show any new growth. It appears that transplanting to a more inundated area will not be successful, due mostly to a lack of pneumatophores (breathing roots) on the small black mangroves. These areas will be planted with *S. alterniflora*. It has also been noted that the larger trees up to 1 m in height are doing better as a group than the smaller trees. In light of this observation an additional sweep through the area for larger trees to be moved will be made. Figures 3 and 4 show views of the transplanted mangroves.

The second project involves mitigation for the destruction of a 1.8 ha intertidal marsh system dominated by smooth cordgrass, *Spartina alterniflora* Loisel. As part of a 93 ha pollution control system designed to prevent low pH discharges into Tampa Bay, this marsh system would be incorporated into the pollution contro pond and eliminated. Requirements by the U.S. Environmental Protection Agency called for creation of a similar size area of marsh as mit gation. A mitigation plan was prepared (Henley Environmental Sciences, Inc. 1977) and a contra awarded to Mangrove Systems, Inc., in March 197 to undertake the planting of *S. alterniflora* from adjacent marshes into an area of upland th was to be graded to the proper elevation and co nected to tidal waters (fig. 5). The original requirements called for 0.5 m spacing of the plugs, but this was later revised to 1.0 m spacing, since previous experiments had determined that the original plugs would completely fill the spaces within 24 months (Lewis and Lew 1977a).

Plugs of *S. alterniflora* were removed fron an existing tidal marsh located immediately nor of the Gardinier, Inc., plant facility. This was the company constructing the pollution control pond. The plugs were 10-12 cm in diameter and were removed using standard post-hole diggers. The plugs were transported intact in sha low plastic trays and placed into holes at 1 m intervals in the planting area within several hours of their removal. One ounce of Osmocote Slow-Release (3-4 month) 14-14-14 fertilizer wa side dressed at each planting site after all tl planting was complete in April 1978.

Figure 6 shows one of the planting areas April 1979. It is the same area shown in Figu 2 in April 1978. Counts of the number of emergent stems (culms) show an increse from $4/m^2$ t

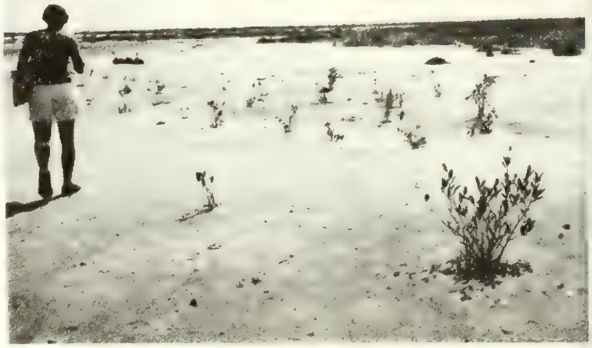

Figure 3.--Black mangroves soon after being moved to spoil island mitigation site.

gure 4.--Single black mangrove two months after transplanting.

0/m². Approximately 25% of the 2,127 plugs d not survive due to an acid discharge that undated the area during a heavy rainstorm in ne 1978. The pollution control pond is, however, fully operational at the present time and ll prevent any further such incidents. The all bare areas resulting from the spill should filled in by spreading of adjacent rhizomes. would perhaps have been better if the reirement for mitigation had been postponed unl the pollution control pond was fully opational, but overall the project has been very ccessful.

The final project involves the creation of extension to an existing dredged material isnd located at the mouth of the Alafia River Tampa Bay. The island (Sunken Island) is one two islands leased by the National Audubon ciety and protected as Sanctuary Islands. The lands support large numbers of tree nesting abirds and wading birds including the Brown lican, White Ibis, and several heron and egt species (Lewis and Dunstan 1975, Lewis and wis 1978, Rodgers 1978). As partial mititition for the impacts associated with the edging of the Tampa Harbor Deepening Project e U.S. Corps of Engineers and the National dubon Society agreed that disposal of a poron of the dredged material would occur at the stern tip of Sunken Island. This island had en created by the original channel dredging r the U.S. Phosphoric (now Gardinier, Inc.) ant on the Alafia River in 1929 along with other island, now known as Bird Island. The iginal Sunken Island had eroded completely ay by 1957, and was recreated by new dredging d disposal at the same site in 1961. The rate erosion has been calculated to be 0.5 ha/yr.

The factors controlling avian usage of dredged material islands in Florida have been discussed in detail by Schreiber and Schreiber (1978) and Lewis and Lewis (1978). It is apparent that many very young islands that may initially provide good habitat for ground nesting species typical of beaches (e.g. Least Terns, Black Skimmers, Caspian Terns) quickly lose this value as they are colonized by plants. Thus Sunken Island and Bird Island had long ago lost their value for ground nesting species. With a decline in available open beach sites, many of these bird species have shown precipitous declines in populations (Kale 1978). The aim, then, of creating an extension to Sunken Island was to provide habitat for ground nesters and actively manage the deposit to maintain a reduced vegetative cover for these species.

The extension was created in November 1977 (fig. 7) and covered a total area of 6.8 ha. By May of 1978 it was being utilized for nesting by 29 pair of Caspian Terns, 125 pair of Black Skimmers, and 220 pair of Least Terns, and was largely barren of plant cover. During the summer of 1978 a number of plant propagules either washed up on the deposit or were carried by birds or airborne seeds. Forty-eight plant species were recorded on the island in October 1978. To reduce this plant cover tilling and other management techniques were started in the winter of 1979. In May of 1979 Black Skimmers and Caspian Terns had returned to the island to nest, and their numbers were approximately 10% greater than last year. No Least Terns have nested this year, probably due to the creation of a very large (263 ha) diked disposal area nearby. Some Laughing Gulls have started nesting in some of the low vegetative cover (primarily Atriplex arenaria). Since this species has a large amount of habitat for nesting, the island will not be managed for its use. In addition, this

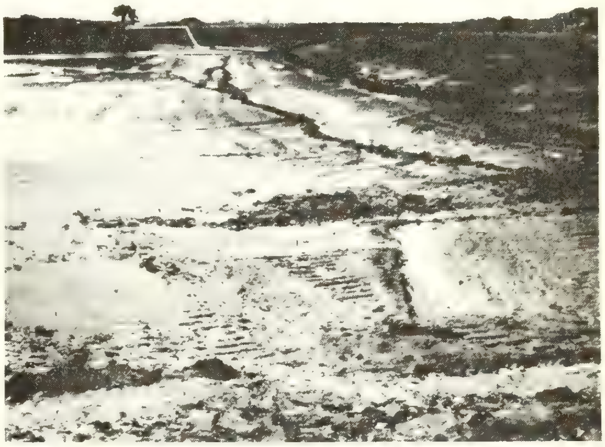

Figure 5.--Marsh mitigation site at Archie Creek prior to planting, April 1978.

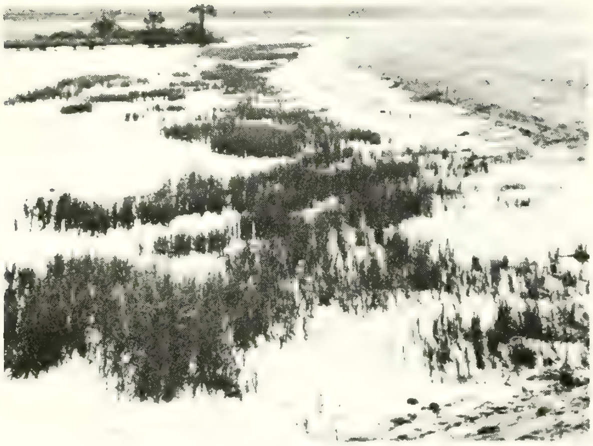

Figure 6.--Marsh mitigation site at Archie Creek, April 1979.

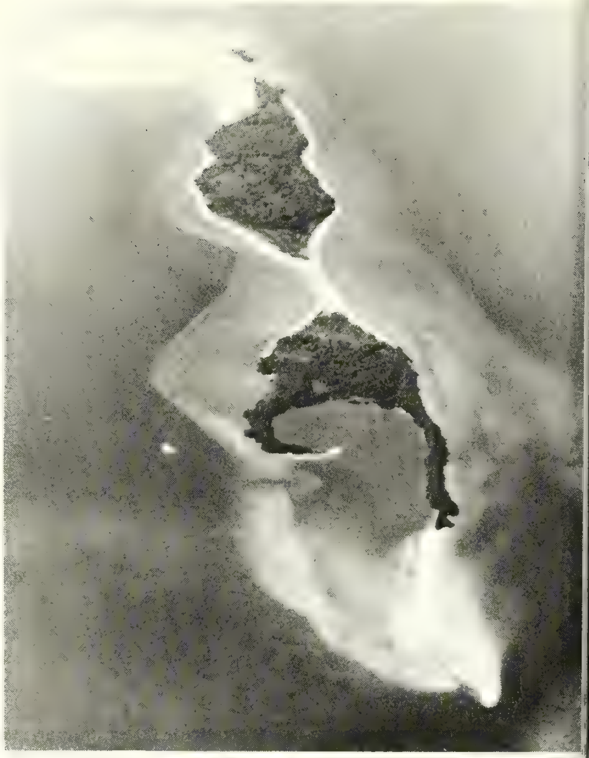

Figure 7.--Aerial photograph of Bird Island (foreground), Sunken Island (upper center) and Sunken Island Extension (upper left), November 1978.

species will prey on eggs and young of the two other species if they are disturbed and leave the nest.

The primary problem at the present time is to provide good habitat for certain species and avoid the inevitable erosion of the deposit which could completely destroy it in 10 years at the present rate of erosion. The first problem is being managed as discussed previously and also by the planting of 8,000 plugs of _S. alterniflora_ by the YACC program to provide wading bird feeding habitat and possible nesting habitat for Clapper Rails. No solution to the second problem has been arrived at at the present time. Experiments with floating tire breakwaters and certain plant species to reduce wind erosion (_Uniola paniculata_, sea oats; _Spartina patens_, salt hay) will be undertaken this summer.

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Mitigation and Grassroots Conservation of Wetlands - Urban Issues[1]

John R. Clark[2]

Abstract.--Case histories from the New York and Los Angeles Metropolitan areas are used as examples of the difficulties that arise in mitigation of impacts in urban coastal wetlands development. Because both the natural values and real estate values of urban wetlands are so high, conflicts between advocates of development and preservation often become extremely serious. Effective mitigation programs are recommended as a potential solution to such conflicts.

INTRODUCTION

Mitigation programs for urban wetlands velopment are faced with special difficulties ing to the extraordinary value of the resource. scarcity of urban real estate available for velopment in most cities often forces developnt pressures toward wetlands. The extreme mand for waterfront real estate often means at land converted from wetlands commands an er higher price than run-of-the-market urban al estate.

On the other hand, very little habitat mains in most cities for aquatically oriented ecies. Therefore, the same wetlands coveted development may have extraordinary value as last place of refuge for many coastal wild-e species. When the two opposing forces meet conflict over a coastal wetland, the battle often prolonged and costly. Soundly based igation programs can serve to resolve some the more difficult conflict situations.

The preferred form of mitigation for urban land projects is on-site mitigation which mits historic natural systems to continue function in place. That is to say, all mage caused by a project should be mitigated thin the development site or project area ere damage occurs. The preferred mode of igation is direct rather than substitute. That is to say, the same functions are to be directly restored, replaced, or compensated as those that are lost. For example, an appropriate water detention system might be a successful direct replacement of drainage control for a loss of natural vegetation in an upland development area. But if a coastal wetland is to be preempted, all wetland functions would have to be replaced, on-site, by a duplicate wetland because it would be nearly impossible to replace a wetland with a combination of artificial substitutes.

Usually the developer and the public will be well served by the use of "performance standards" to formulate mitigation requirements for urban wetlands. In this approach, the specific properties and characteristics of the natural system that must remain after development are defined. Accordingly, the developer is allowed to proceed with the project if he can show proof that the natural system will still "perform" according to prescribed "standards." In this way, the developer is free to devise any approach to the project which will guarantee function of the natural system and not cause public harm. A performance standard might be the quantity of duck a pond shall produce, the quality of water that passes from a parcel of land, the amount of water current flowing through an estuary, or the uptake of pollutants by a wetland.

The case histories that follow demonstrate some important points about urban wetlands mitigation at the local, "grassroots," level. The New York case shows the extent of engineering effort that is often put into urban wetlands conservation and mitigation. The California cases show the extent to which local and state interests will go to gain protection for urban wetlands.

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[1] Paper presented at The Mitigation Sympom, Colorado State University, Fort Collins, orado, July 16-20, 1979.

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DEFINITIONS

The term "mitigation" is used in many different and often conflicting or ambiguous ways. This is because it is an "umbrella" term which covers so broad a field as to be open to nearly unlimited interpretation. Yet, one can narrow the subject down by the use of appropriate terminology. The following definitions are used in this paper:

1. *Enhancement* is a form of mitigation that simply implies improvement of an ecosystem; for example, enhancement would be improving or restoring water circulation, plant growth, or a species habitat whether as a *quid pro quo* or just because its a good idea.

2. *Minimization* (or reduction) of impact is a form of mitigation that implies unavoidable ecological damage from some development activity and seeks to reduce it to the minimum; for example, minimization would be preventing the spread of silt in dredging, not bulldozing in breeding time to avoid disturbing an adjacent eagle nest, or reducing entrainment of a power plant.

3. *Compensation* is a *quid pro quo* form of mitigation that implies the trade-off of an unavoidable ecological loss for an ecological improvement; for example, the enhancement and dedication of a piece of upland game habitat as a trade-off for some riparian habitat lost to a reservoir.

4. *Replacement* is a *quid pro quo* exchange of a particular resource for another of the same type; for example, 10 acres of new *Spartina* marsh built on dredge spoil to replace 10 acres lost to marina development.

5. *Indemnification* is a *quid pro quo* form of mitigation that implies a monetary recompense for loss of ecological resources; for example, the payment to a public agency of a million dollars in cash for damages to 10 acres of urban wetland converted to housing sites.

Restoration is a secondary term. It might apply to a required enhancement mitigation, to a tax supported public capital budget project, or to a specific court-imposed penalty required for an illegal (non-permitted) or an irregular (exceeds performance standards) project.

NASSAU EXPRESSWAY

The Nassau Expressway assessment project involved the alignment, design, construction, and operation of an expressway extension, part over coastal wetlands of the Jamaica and Hempstead Bays ecosystems. I served as coordinato of a wetlands research team which assessed the ecological effects of a variety of alternative approaches and which advised Vollmer Associate the prime E.I.S. contractor, and the State and Federal Departments of Transportation on the least damaging alternatives and best mitigatio techniques (EGG, 1977). Much of the material used in this section was provided by the courtesy of Mr. Pat Monte of Vollmer Associate with the consent of the New York State Department of Transportation (some of the data are not yet final and are subject to change).

Because the interaction between engineers and ecologists began early in the feasibility process it was possible to openly consider the widest variety of approaches. This led to the best practicable mitigation strategy. The process was guided by the Environmental Actio Plan, a system developed by the New York DOT for federally-aided transportation projects to assure full consideration of socio-economic and environmental factors. The objectives of this system are:

--To involve other agencies and the publ in the transportation planning and develo ment process early enough to influence technical studies and decisions.

--To identify social, economic and envir mental effects early enough in the proce to lead to consideration of beneficial alternatives.

The Project

The Nassau Expressway was proposed as a four to six lane divided highway linking the Southern Parkway in Queens County, New York City to the Atlantic Beach Bridge in Nassau County, a distance of about ten miles. Withi the city, the project corridor abuts the northerly boundary of the John F. Kennedy International Airport. In Nassau County, it proceeds through residential neighborhoods ending at the Atlantic Beach Bridge.

The Planning for the Nassau Expressway sought solutions providing overall improvemen of travel in the corridor compatible with the specific concerns of local areas. Three approaches were pursued:

--A no-build alternative: The decision not to construct any portion of the Nassau Expressway, but to continue to maintain existing facilities and services.

--An expressway alternative: An expressway-type design throughout the entire length of the corridor, that is, a divided highway with full control of access and no crossings at grade.

--A boulevard alternative: A lesser scale than the full expressway alternative, it combines expressway with boulevard design with signalized at-grade intersections where practical.

The project was divided into five Sections (A, B, C, D and E). In each section, the process of developing alternates narrowed to two, reflecting either a level of traffic operation (expressway versus boulevard), a variation in access, or a variation in location. Table 1 summarizes key features and differences between the section alternates under consideration.

The impact assessment had to satisfy "Section 4(f)" tests (U.S. regulation requiring exploration of "feasible alternatives" to use of any park lands) because of a designated city park, Idlewild Park, as well as the requirement of NEPA and State wetland protection regulations. The assessment (presently in a preliminary EIS draft by Vollmer Associates) addressed social, economic, land-use, air quality, noise, and wetlands as principal concerns. This paper addresses only the wetlands aspects of the proposed project and focuses on the wetlands mitigation aspects.

Table 1. Key features and differences for each of five design alternates for the Nassau Expressway Project.

Design Section	Section Alternate	Design Difference
A (Cross Bay Blvd. to Van Wyck Expwy.)	A-I Expressway (minimizes Park Impact) A-II Expressway (Improved Access to Aquaduct Race Track)	Location and Access
B (Van Wyck Expwy. to 156th Street)	B-I Expressway (Using Van Wyck existing Service Roads) B-II Expressway (new Van Wyck Expwy. Collector Roads	Location and Access
C (156th St. to Brookville Blvd.)	C-I Expressway C-II Boulevard	Traffic Operation
D (156th St. to Brookville Blvd.)	D-I Expressway (Uses previous R.O.W. D-II Expressway (adjacent to Rockaway Blvd.)	Location
E (Burnshide Ave. to Atlantic Beach Bridge)	E-I Expressway E-II Boulevard	Traffic Operation

The Strategy

The approach was to reduce the amount of wetlands altered to an insignificant level for both the 139 acres of the Jamaica Bay system and the 91 acres of the Hempstead Bay system that would be affected. Our major concern narrowed down to Sections C and D which involved salt marsh still remaining behind the J.F.K. International Airport fill (figure 1). Section E also was of concern. The following objectives guided the wetland impact minimization and mitigation analysis:

1. Insignificant net loss of wetland surface area.
2. Zero loss of potential wetland capability.
3. Maximum feasible restoration of wetland function.

The original trial alignments of the Expressway would have caused appreciable loss of wetlands. As the dialog between ecologists and engineers continued, alignments were adjusted, designs were altered, construction methods improved, and mitigation opportunities delineated. For each alternative, a series of measures was proposed to mitigate impacts, including creation of new wetlands, drainage channels, improved tidal circulation, and the use of viaducts to carry the roadways over the wetlands. Based upon these measures, the maximum impact of any set of Section Alternates throughout the corridor was shown to be a net loss of 6.2 acres (Alternates C-1, or C-II, D-IB, and E-IIB) and the minimum impact is a net gain of 0.2 acres (Alternates C-I or C-II, D-IA, E-IA). Selection of environmental alternatives was constrained by project costs, engineering state-of-the-art, and by airport safety requirements.

Results: Section C

Existing Conditions: The wetlands complex of Section C consists of a total of 135 acres of Intertidal Marsh and 63 acres of High Marsh, all in New York City (figure 2). Until recently, 75 to 80 percent of the original acreage could have been considered as tidal marsh with the characteristics of any estuarine area. However, in the early 1970's construction waste landfill placed by New York City reduced wetlands acreage to less than 50 percent of its original total. The filling operation has been stopped by the State Environmental Conservation Department.

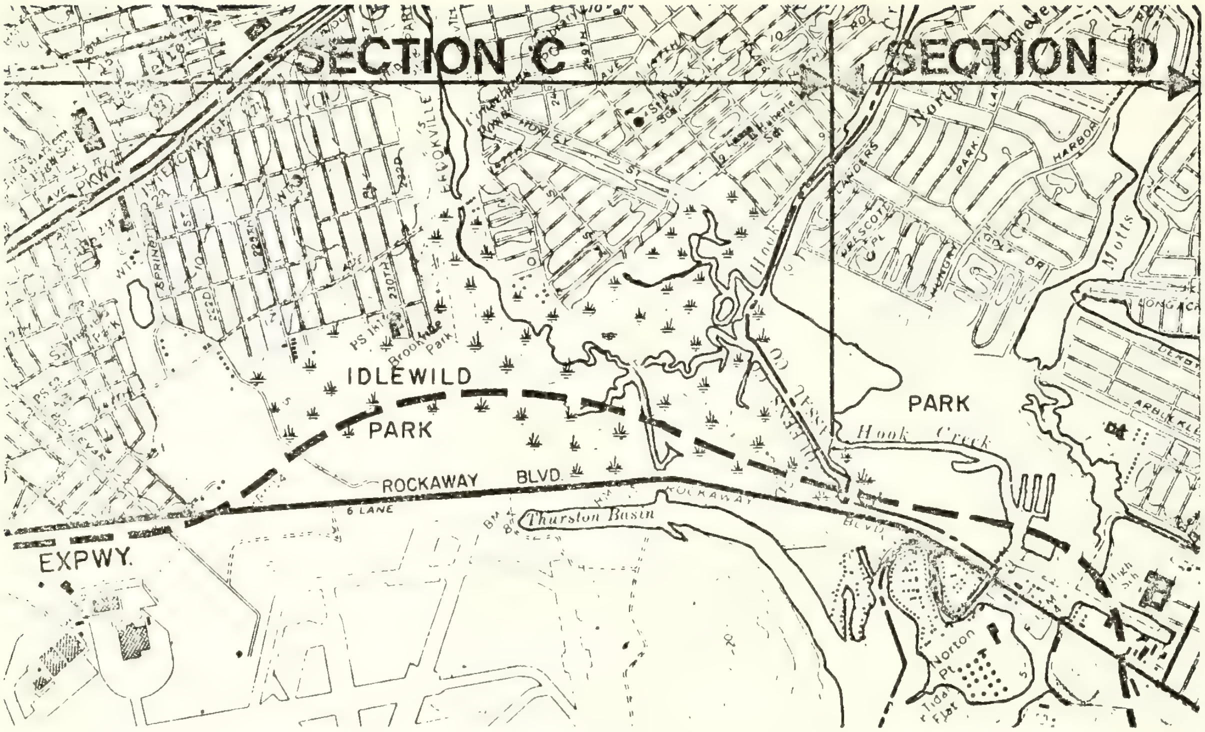


Figure 1. Wetlands in Sections C and D of the Proposed Nassau Expressway

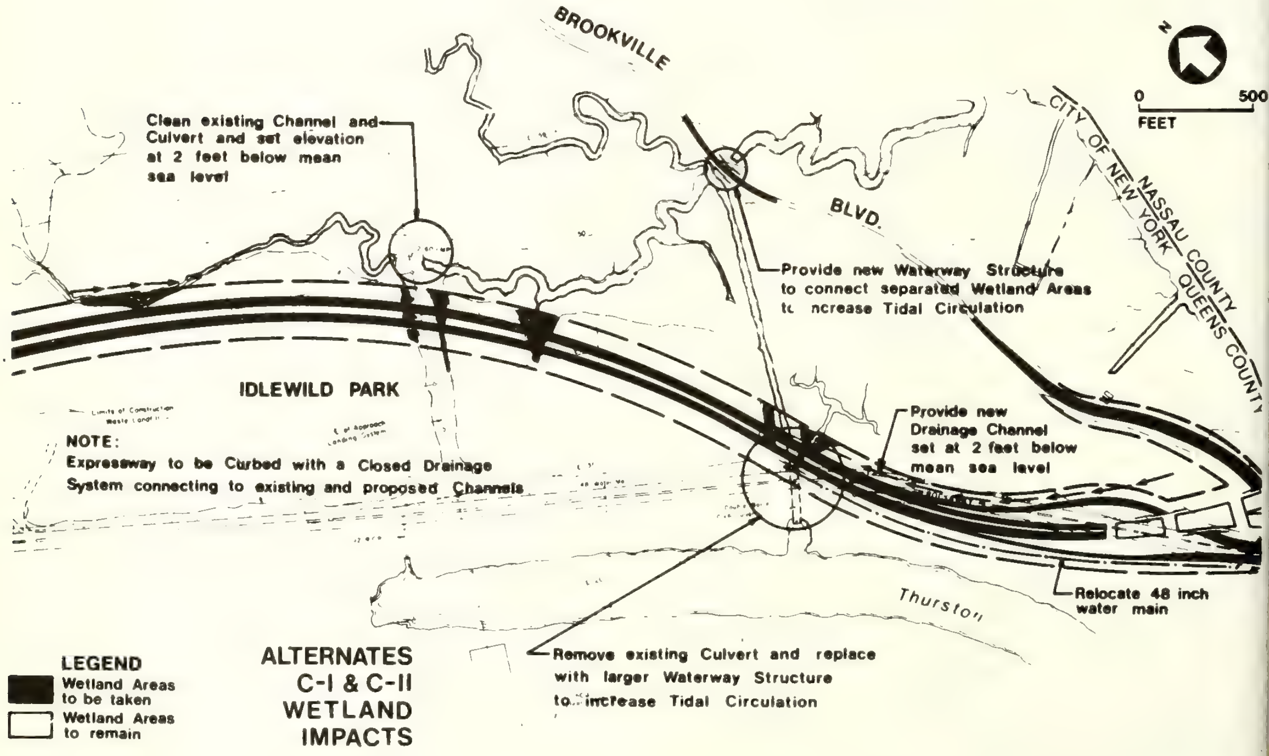

BROOKVILLE
BLVD.
0
500
FEET
CITY OF NEW YORK
NASSAU COUNTY
QUEENS COUNTY
Clean existing Channel and Culvert and set elevation at 2 feet below mean sea level
Provide new Waterway Structure to connect separated Wetland Areas to increase Tidal Circulation
IDLEWILD PARK
NOTE:
Expressway to be Curbed with a Closed Drainage System connecting to existing and proposed Channels
Provide new Drainage Channel set at 2 feet below mean sea level
Relocate 48 inch water main
Thurston
Remove existing Culvert and replace with larger Waterway Structure to increase Tidal Circulation
LEGEND
■ Wetland Areas to be taken
☐ Wetland Areas to remain
ALTERNATES C-I & C-II WETLAND IMPACTS

Figure 2. Section C showing major mitigation features for Alternates C-I and C-II.

Drainage from the marshes of Idlewild Park and Brookville Park Addition feeds Thurston Basin via a restricted culvert beneath Rockaway Boulevard. The Public Place marshes have been separated from Idlewild Park by landfill for Brookville Boulevard and now connect to the Hook and Mott Creeks system.

Impacts: Alternates C-I and C-II do not vary in their impact upon the wetlands since only one alignment is proposed near the wetlands. This alignment would be located in the landfill adjacent to the wetlands and only come into contact with pockets which protrude into the landfill areas. The net wetlands effect would be:

Wetland Category	Area Affected
Intertidal Marsh	-1.8 acres
High Marsh	-0.6 acres
New Wetlands Created	+1.7 acres
Net Change	-0.7 acres

This slight impact is achieved by the selection of an alignment purposely intended to minimize wetlands taken and by creation of new areas.

Mitigation: In addition to the creation of new wetlands, a series of additional mitigation measures were developed as an integral part of the Nassau Expressway project to both compensate for and upgrade existing wetlands affected.

New waterway structures will be provided to connect littoral zones presently separated by the embankment of Brookville Boulevard and to increase the size of an existing double barrel 10' x 6' box culvert under existing Rockaway Boulevard. Providing these structures will increase tidal flushing action within the wetlands and will therefore improve their overall quality and productivity.

Additional measures include construction of tidal circulation channels to accept drainage runoff from the expressway, cleaning and resetting culverts under the light approach system of Runway 22L, cleaning and lowering of existing tidal channels and culverts where required, placement of stone fill for culvert and channel protection, and other features.

Short-term (construction) impacts will be minor for the Section C Alternates. Crossing the major creek which drains into Thurston Basin along the southeastern edge of the landfill can disrupt circulation and water quality in the creek, but its duration and extent can be minimized. Specifications for the construction can assure adequate passage of water. Siltation problems can be restricted to the immediate zone of operation in the wetlands and prevented from affecting Thurston Basin and deeper waters by the use of earthworks, settling basins, silt curtains, etc. It is anticipated that the adjacent landfill area not utilized for highway purposes will be used for the disposal of unsuitable material excavated from within the landfill area itself and from Section D.

Results: Section D

Existing Conditions: Hook and Mott Creeks wetlands of Section D are an isolated marsh area of 23.3 acres, including about 4.6 acres of Intertidal Marsh, 16 acres of High Marsh, and 2.7 acres of mudflats and shoals (figure 3). Other wetlands in Section D, lying north of Burnside Avenue consist of 4.4 acres of Formerly Connected and 12.6 acres of High Marsh areas which connect with the Head of Bay.

Impact: The wetlands of Hook and Mott Creeks will be substantially affected by even the best of the proposed alignments. Two construction methods are available between Hook and Mott Creeks which vary in construction costs versus wetlands impact. D-IA is a viaduct that traverses the entire wetland area. D-IB is a combination of viaduct and fill sections. Construction of the viaduct sections will be done from the previously completed viaduct span in a "leap frog" operation thereby minimizing disturbance to the wetlands during construction (figure 4). The cost of the fill and viaduct option (Alternate D-IB) is estimated at approximately nine million dollars less than the full viaduct option (Alternate D-IA).

The net wetlands effect for the Hook and Mott Creeks system are:

Wetland Category	Viaduct Option Alternate D-IA	Fill Option Alternate D-IB
Intertidal Marsh (IM) taken	- 1.0	- 1.0
High Marsh (HM) taken	- 3.5	- 11.4
Shoals taken	- 0.1	- 0.1
Newly created IM	+ 3.4	+ 3.5
Converted from HM to IM	-	+ 2.3
Other Wetlands Created	+ 2.2	+ 2.6
Net Change	+ 1.0	- 4.1

In addition to the Hook and Mott Creeks wetlands, 4.1 of the 4.4 acres of formerly connected wetlands north of Burnside Avenue will be required for the proposed construction. Alternate D-IB (fill) has the potential for the greatest wetlands impacts. Construction of the Expressway on fill behind the Shopping

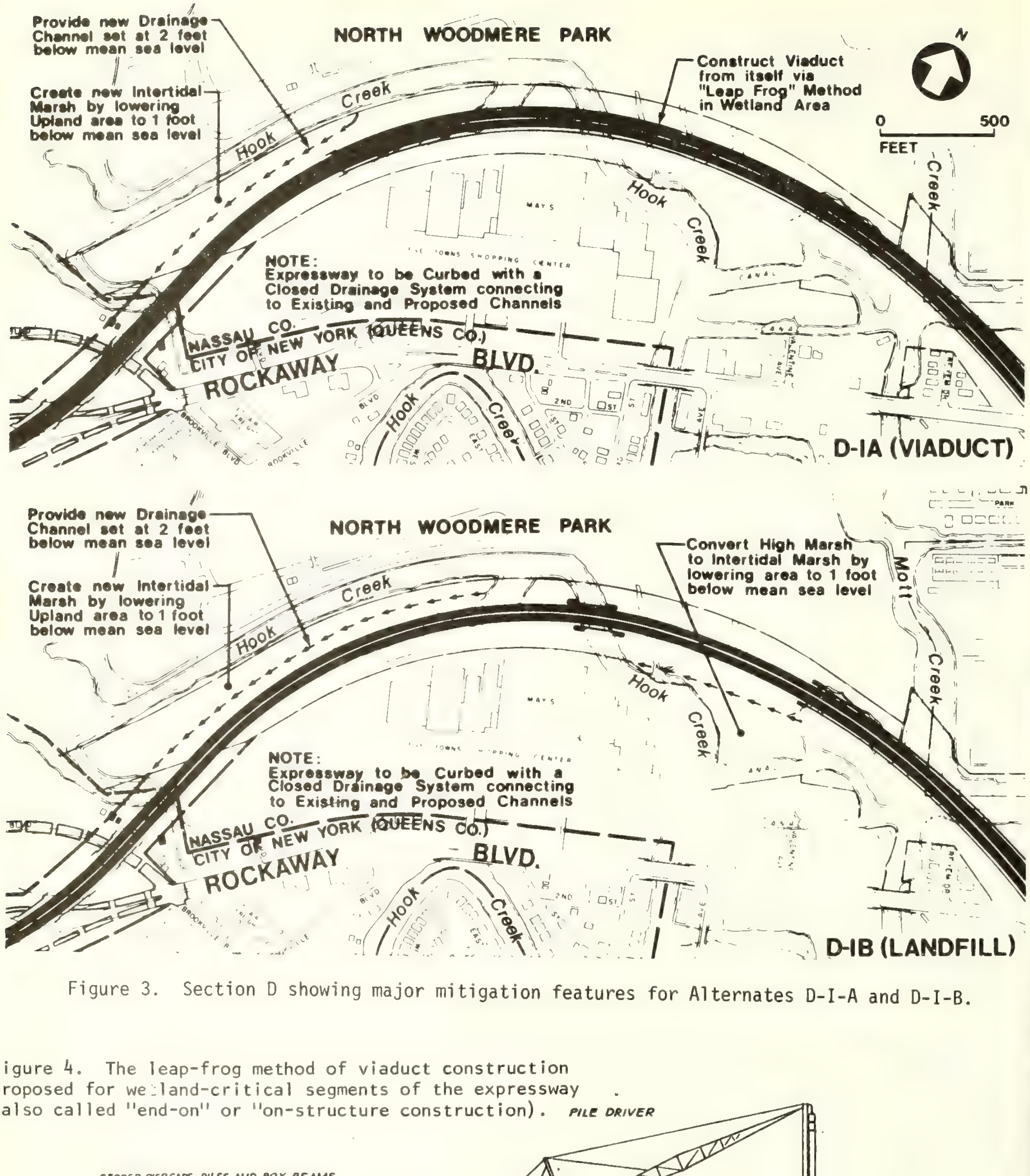
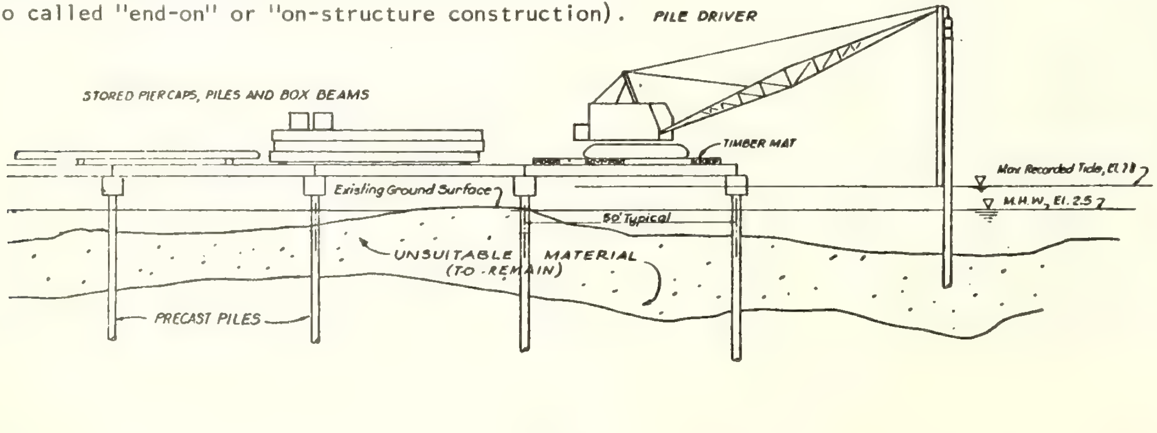

Provide new Drainage Channel set at 2 feet below mean sea level
NORTH WOODMERE PARK
Construct Viaduct from itself via "Leap Frog" Method in Wetland Area
N
0
500
FEET
Create new Intertidal Marsh by lowering Upland area to 1 foot below mean sea level
Hook Creek
Hook Creek
Creek
NOTE: Expressway to be Curbed with a Closed Drainage System connecting to Existing and Proposed Channels
NASSAU CO.
CITY OF NEW YORK (QUEENS CO.)
ROCKAWAY BLVD.
Hook Creek
D-IA (VIADUCT)
Provide new Drainage Channel set at 2 feet below mean sea level
NORTH WOODMERE PARK
Convert High Marsh to Intertidal Marsh by lowering area to 1 foot below mean sea level
Mott Creek
Create new Intertidal Marsh by lowering Upland area to 1 foot below mean sea level
Hook Creek
Hook Creek
NOTE: Expressway to be Curbed with a Closed Drainage System connecting to Existing and Proposed Channels
NASSAU CO.
CITY OF NEW YORK (QUEENS CO.)
ROCKAWAY BLVD.
Hook Creek
D-IB (LANDFILL)

Figure 3. Section D showing major mitigation features for Alternates D-I-A and D-I-B.

Figure 4. The leap-frog method of viaduct construction proposed for wetland-critical segments of the expressway (also called "end-on" or "on-structure construction).


PILE DRIVER
STORED PIERCAPS, PILES AND BOX BEAMS
TIMBER MAT
Max Recorded Tide, El. 7.8
M.H.W., El. 2.5
Existing Ground Surface
50' Typical
UNSUITABLE MATERIAL (TO REMAIN)
PRECAST PILES

Center with bridges across Hook and Mott Creeks would cause a virtual total loss of the marshes, benthic and fish life in the right-of-way. The D-IB Alternate also requires a difficult soils treatment operation. Removal of unsuitable base material and subsequent refilling will severely impact the area regardless of the removal techniques used (mechanical-dragline, or hydraulic dredging). The fill option would also create the greatest restrictions on tidal circulation.

Alternate D-IA, the viaduct behind the shopping center, requires a narrower area through the wetlands, which considerably reduces the immediate impact zone and causes minimum damage. The viaduct can be built from itself (leap frog method), which not only minimizes areas lost to actual roadway, but it substantially reduces construction damage to areas adjacent to the roadway. Also, more of the Hook Creek bottom and shore would be left intact than with the fill option, substantially reducing siltation and other water quality impacts of wetlands construction.

The viaduct will also create minimal tidal circulation restriction. Stormwater runoff will be through continuous open gratings running the full length of the viaduct. This system will avoid the high quantity and velocity discharge of inlet and pipe systems where runoff is collected and discharged at points. Channels will be provided beneath the viaduct gratings. The channels will outlet into Hook and Mott Creeks.

The viaduct will create minimal negative impact to this area relative to the multiple impacts of the landfill options.

Mitigation: Proposed wetlands mitigation and enhancement measures for both options consists of the construction of new tidal circulation channels plus lowering of a non-wetlands area near the City/County line to one foot below mean sea level to create a new Intertidal Marsh area. The channels, to be constructed at a depth of two feet below mean sea level, will accept the runoff from the roadway before it enters the wetlands area and will also serve to convey tidal waters to the newly created wetland areas. In addition to the above, a High Marsh area will be lowered to Intertidal Marsh in the fill option.

Cost of mitigation measures are $285,000 for Alternate D-IA and $330,000 for Alternate D-IB.

Results: Section E

Existing Conditions: The Bannister Creek wetlands include approximately 91 acres along the western edge of the Lawrence Marsh (figure 5). The bulk of the 1,000-acre Lawrence Marsh lies along Reynolds Channel, east of the project area.

The Bannister Creek system consists of approximately 51 acres of Intertidal Marsh, 18 acres of High Marsh, 5 acres of Formerly Connected Marsh and 17 acres of shoals and mudflats. Bannister Creek has been altered from its natural state by bulkheading, dredging and landfilling. A culvert under Doughty Boulevard restricts tidal circulation to formerly connected wetlands west of Doughty Boulevard.

Impacts: While the wetlands would be affected by either a "wall" or a "fill" option, there would be a net gain in wetlands acreage and an improvement in quality by creation of more intertidal wetland. These effects are shown below:

Wetlands Category	E-IA Wall Option	E-IB Fill Option
Intertidal Marsh taken	- 0.9	- 1.1
High Marsh taken	- 1.2	- 1.6
Shoals and Mud Flats taken	- 0.9	- 1.0
Formerly Connected taken	- 1.2	- 1.1
Newly-Created Intertidal Marsh	+ 6.1	+ 5.6
Other Wetlands created	+ 2.1	+ 2.1
Net Gain (+) (Acres)	+ 4.0	+ 2.9

Mitigation: The primary mitigation measure for this area is the creation of the new Intertidal Marsh from formerly connected wetlands. This entails replacing an existing culvert with a larger one and adding a second large culvert beneath the proposed roadway to increase tidal flow to a level sufficient to maintain a viable wetland (one foot below mean sea level). Additional tidal channels constructed east of the Expressway would connect the new culverts to Bannister Creek. Some areas east of the Expressway would also be converted to an Intertidal Marsh area.

Estimated cost of mitigation measures is $450,000 for E-IB and $470,000 for E-IA.

LOS ANGELES WETLANDS

Under the California Coastal Act of 1976, the state may allow a marina to be sited in a wetland area and may permit channel and basin dredging and necessary filling but only in a "degraded" wetland area and only if a substantial amount is restored (at least 4 times the acreage used for the marina). Moreover it can be done only if this is deemed the "most feasible" way to restore (enhance) the degraded

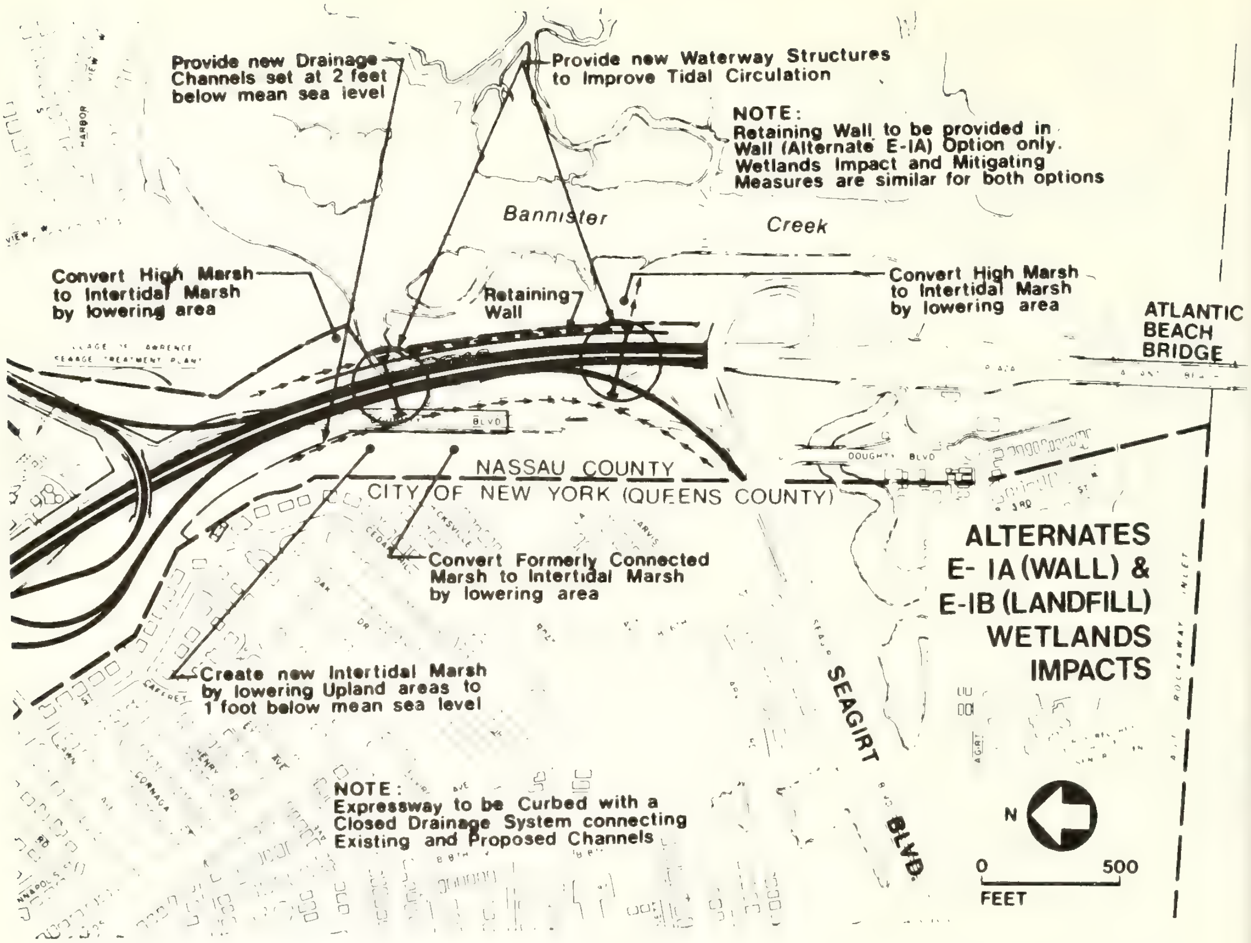

Provide new Drainage Channels set at 2 feet below mean sea level
Provide new Waterway Structures to Improve Tidal Circulation
NOTE:
Retaining Wall to be provided in Wall (Alternate E-IA) Option only. Wetlands Impact and Mitigating Measures are similar for both options
Bannister
Creek
Convert High Marsh to Intertidal Marsh by lowering area
Retaining Wall
Convert High Marsh to Intertidal Marsh by lowering area
ATLANTIC BEACH BRIDGE
BLVD
DOUGHTY BLVD
NASSAU COUNTY
CITY OF NEW YORK (QUEENS COUNTY)
ALTERNATES E- IA (WALL) & E-IB (LANDFILL) WETLANDS IMPACTS
Convert Formerly Connected Marsh to Intertidal Marsh by lowering area
Create new Intertidal Marsh by lowering Upland areas to 1 foot below mean sea level
SEAGIRT BLVD.
NOTE:
Expressway to be Curbed with a Closed Drainage System connecting Existing and Proposed Channels
N
0
500
FEET
ROCKAWAY INLET

Figure 5. Section E showing major mitigation features for alternates E-I-A and E-I-B.

wetlands. (Indemnification is possible under California law but its use is not anticipated.) This permission is being discussed for the Ballona Wetlands and tested for the Bolsa Chica Wetlands in the Los Angeles Greater Metropolitan Area. The extraordinary value of Los Angeles area wetlands for conversion to real estate (it may be worth up to $400,000 per acre in some situations) makes this provision exceptionally vulnerable to legal attack and political maneuvering by developers. The extraordinary scarcity of viable wetlands habitat in the Los Angeles area makes these vestiges of a once great wildlife resource very precious to nature conscious citizens who rally strong forces to protect them as endangered habitats.

Thus , as both wetlands habitats and open real estate become scarce in Los Angeles, as in many cities, the conflicts over their use become exacerbated. Solutions are hard to come by, replacement mitigation is nearly out of the question, and enhancement and impact mitigation are the best handles. These subjects are explored briefly in this section. The source of information for the Ballona Wetlands is a study conducted at UCLA and supervised by the author (Clark, 1979). The information for the Bolsa Chica Wetlands is from studies conducted by the U.S. Fish and Wildlife Service (Long Beach, California) (USFWS, 1979).

Ballona Wetlands

The wetlands lying within the "Ballona Gap" of coastal Los Angeles County, along with their adjacent lagoons and shallows, originally (early 1800's) covered 2,100 or more acres. While much of this has been irretrievably converted to other uses, about 517 acres are either actual wetlands or are vacant land that once was and again could be wetlands if a sufficiently large-scale commitment were made to restoration. Acreages are roughly as follows: 118 acres of existing functioning wetlands, 243 acres of wetlands that are easily restorable to function, and 156 acres of wetlands more difficult to restore.

The wetlands as a whole are suffering from deprivation of tidal flushing. The problem is caused by dikes, berms, fills and roads which were built many years ago before the high values of wetlands were appreciated. It appears that simple grading and reshaping of the wetland surface along with improving water flows and providing edge-zone buffers would restore much of the Ballona Wetlands west of Lincoln Boulevard to a nearly natural level of function. The wetlands are, even in their altered state, performing typically valuable natural salt marsh functions.

The question the Ballona study grappled with is how these wetlands can be preserved in a long-term functioning condition in view of the press of urban development in Los Angeles County. The title holder to the Ballona Wetlands, the Summa Corporation, has released a concept plan (April, 1979) which would preempt most of the former and existing wetlands in the Ballona area for intense urban development. Under Federal and state laws and programs concerned with wetlands conservation, as well as County ecological protection policies, the use of wetlands for such general urban development would normally be disallowed. Only if the marina-and-restoration option were invoked would the title holder find an easy solution to converting wetlands to development. But this would mean giving up development options for the restored part.

Figure 6 shows the Ballona area in West Los Angeles. Sub-tract A is a filled area (+10-15 ft. m.s.l.) with a central depression that supports a perched 40-acre seasonal Salicornia wetland. It is separated from Sub-tract B by a concretized flood control channel. This 139-acre sub-tract is ideally located for a marina development (up to 2,500 boats) because it is adjacent to the Marina del Rey, an 804-acre marina created by dredging wetlands twenty years ago.

Sub-tract B is a 300-acre wetland in varying states of degradation which could greatly benefit from restorative enhancement. But this would mean that plans for development would have to be greatly altered. However, intensified development to the east of the wetlands in the Summa tract could compensate for development foregone in the wetlands.

It remains to be seen whether the various Federal, state, and county regulatory agencies would permit sacrifice of the seasonal wetlands in Sub-tract A for a marina in order to facilitate enhancement of Sub-tract B as mitigation. However, in the author's opinion it seems a reasonable tradeoff.

Bolsa Chica Wetlands

Further south in Orange County lies the Bolsa Chica wetlands. The major title holder, Signal Landmark Corp., has been attempting to convert most of the remaining 1,000 acres of variously degraded wetland for mixed urban development. A very complicated contest between Signal and the State of California over ownership of the salt marsh area was settled in a manner that prescribes certain mitigative measures. The arrangement, which has bred extreme conflict, would have met with little resistance outside the urban setting where the area is worth so much for either wildlife habitat or real estate.

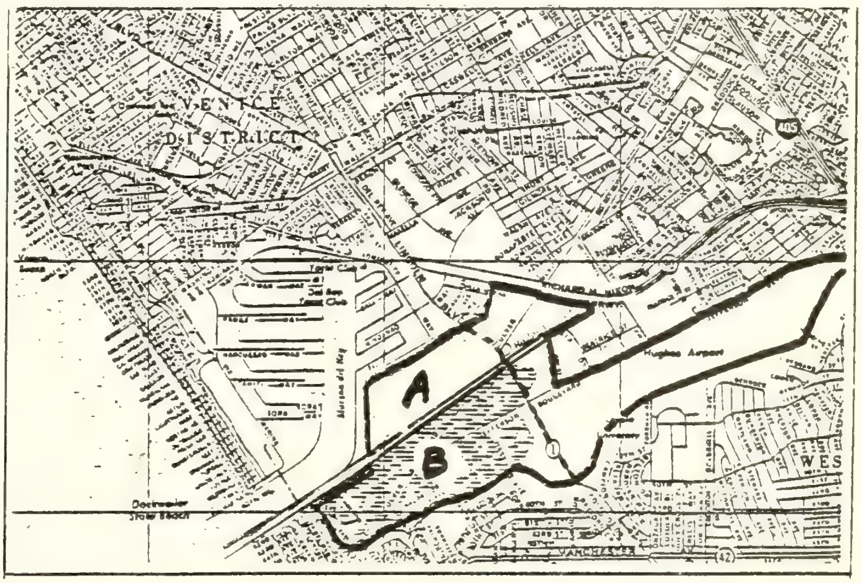


Figure 6. The Ballona study area in West Los Angeles. Summa Corp. tract (926 acres) is within heavy line. A is the potential marina site in altered wetland area. B is wetland in need of restoration.

The Bolsa Chica was once a rich wetland-estuary complex. Now it is surrounded by urban, recreational, and industrial development. It has been dredged, filled, drained, and criss-crossed by roads for oil wells. Of a wetland complex which once covered over 30 square miles, less than 2 square miles remain.[1]

In 1973, the State of California and Signal finally reached an out-of-court settlement. The State terminated the public trust to the tidelands of the Bolsa Bay. In return, Signal deeded to the State 327.5 acres which included the easement of Pacific Coast Highway and a section of wetlands to establish an ecological reserve as a mitigation arrangement. In addition, Signal leased to the State an adjacent 230-acre parcel for 14 years. If, at the end of the 14 years, there was a publicly funded ocean entrance, navigation channel, and approved marina permit, this parcel would also be deeded to the State. The land deal has since been repudiated by several environmental groups and questioned by the U.S. Fish and Wildlife Service.[1]

The State of California assumed sponsorship of a U.S. Army Corps of Engineers feasibility project on building a small craft harbor in the wetlands. Due to the continued opposition mounted by environmental groups, the Corps of Engineers was authorised in 1976, under the Hannaford Resolution, to investigate marsh restoration within Bolsa Chica Ecological Reserve. A Phase I project was designed to place 150 acres of the Bolsa Chica under tidal influence by diking off the area from the rest of the wetlands area to ensure that it would not be inundated by restored tidal flows. The State also built nesting islands for the federal endangered California least tern. The $701,000 project was dedicated in November 1978 (USFWS, 1979). (See Figure 7)

Concurrent with this program, developers completed 75 acres of landfill with no federal permits and without mitigation in an area that the U.S. Fish and Wildlife Service classifies as bonafide wetlands.[1] By early 1979, this

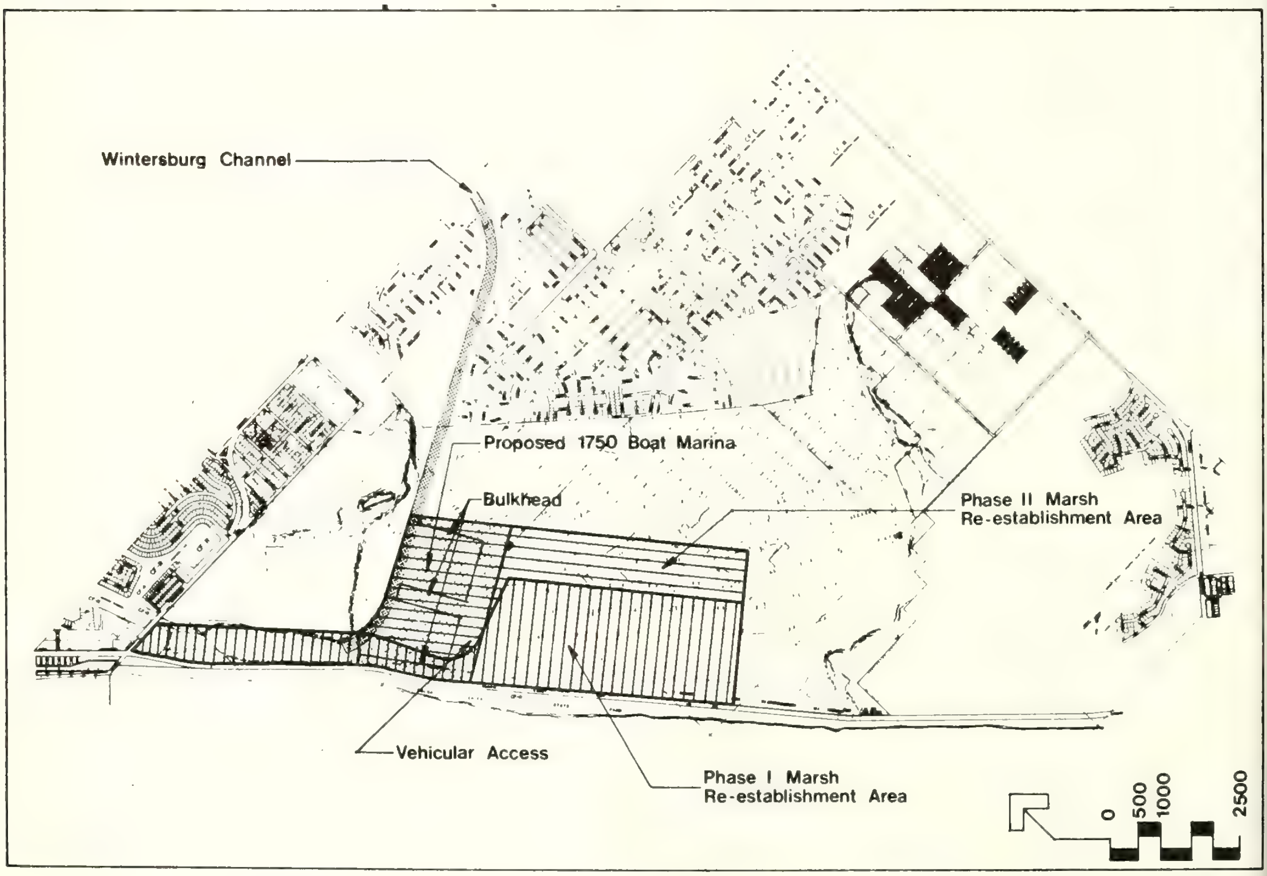

Wintersburg Channel
Proposed 1750 Boat Marina
Bulkhead
Phase II Marsh Re-establishment Area
Vehicular Access
Phase I Marsh Re-establishment Area
0
500
1000
2500

Figure 7. Plan for constructing a 1,750-boat small craft harbor in the Bolsa Chica wetlands. (Source: EDAW, Inc.)

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[1] Unpublished information transmitted by Sharon Lockhardt, U.S. Fish and Wildlife Service, Long Beach, California.

had provoked a lawsuit by the principal citizens group in opposition--Amigos de Bolsa Chica--who were already unhappy with the terms of the 1973 settlement and the built-in mitigation program.

How the 150-acre private marina proposal will fare in this crisis-prone situation remains to be seen. It is obviously in trouble if a major Federal agency and the principal environmental group remains in opposition. The danger of an arranged settlement for extremely valuable urban wetlands has been made clear. The lesson is to engender the widest possible dialog and to make sure that all powerful interests are satisfied with uses, mitigation requirements and performance standards. This can best be done in the context of formal environmental mediation which is recommended for Ballona (Clark, 1979), but was not employed at the Bolsa Chica.

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Mitigation of Fish and Wildlife Habitat Losses in Great Lakes Coastal Wetlands[1]

Eugene Jaworski and C. Nicholas Raphael[2]

Abstract.--Historical analyses indicate that 71 percent of Great Lakes coastal wetlands have been lost. Habitat enhancement measures which reduce nutrient and sediment loading from polluted land drainage may be the most important mitigation strategy. Fish habitat, and fish stocks dependent on wetlands and tributaries, deserve highest priority.

INTRODUCTION

Until recently, little research has been conducted in the Great Lakes coastal wetlands. Much of this previous but limited research has dealt with waterfowl (e.g., Hunt and Mickelson 1976), whereas data are presently being collected with regard to dredge and fill permit review, critical area designations, and environment impact assessment (e.g., Jaworski and Raphael 1978b; Tilton et al. 1979). Although strategies are being formulated with regard to rehabilitation of Great Lakes ecosystems (Christie 1979; Great Lakes Fishery Commission 1978), restoration of developed wetlands or enhancement of degraded wetlands has not progressed beyond traditional diking and water level management practices.

WETLAND RESOURCE BASE

Recent data suggest that there are 676 kilometers of wetland shoreline and 77,328 hectares of wetlands area along the United States' portion of the Great Lakes mainland coast (Table 1). Although precise data must await the results of the national wetlands inventory, this quantity amounts to 11.3 percent of the United States' shoreline length. Of the total 77,328 hectares, approximately 80 percent or 62,753 hectares have been designated as significant fish and wildlife habitat (Great Lakes Basin Commission 1975b). Large tracts of high value wetlands occur in the St. Marys River, western shore of the Green Bay, along Saginaw Bay, St. Clair delta, southwestern shore of Lake Erie, and south-central Lake Ontario.

Table 1.--Extent of Coastal Wetlands along the Great Lakes, USA only

Lake	Shoreline Length	Area[1]
Superior	145	8,097
Michigan	152	18,219
Huron	263	20,243
St. Clair	29	8,097
Erie	30	14,170
Ontario	57	8,502
TOTAL	676 Km	77,328 ha

[1] Estimated from Great Lakes Basin Comm. 1975a; Ohio State Univ. and Indiana Univ., in prep.; and, Jaworski and Raphael 1978b.

A historical analysis of selected coastal wetlands in Michigan revealed that 71 percent of the resource base has been lost to competing land uses (Jaworski and Raphael 1978b). Agricultural encroachment, as initiated by the Swamp Acts of the 1800's, probably accounted for over half of the total wetland loss (Kaatz 1955; Jaworski and Raphael in press). Since the 1940's the main causes of loss appear to be power plant construction, industrial expansion, harbor development, and residential growth. Current projections suggest that 20 percent of extant resource base may be lost during the next decade (Martz 1976).

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[1] Paper presented at The Mitigation Symposium, held at Colorado State University, Fort Collins, CO, July 16-20, 1979.

[2] Associate Professor and Professor, respectively, Dept. of Geography-Geology, Eastern Michigan University, Ypsilanti, MI 48197.

In response to Great Lakes water level changes, the coastal wetlands may increase or decrease in areal extent by as much as 13 percent (Jaworski, Raphael et al. 1979). These natural water level fluctuations, which occur over a hydroperiod of 12 to 20 years, have prompted public and private landowners to dike an estimated 40 percent of the Great Lakes wetlands. Because the amplitude of these water level fluctuations is nearly 2 meters, the function and value of the wetlands change dynamically. In general, higher lake levels enhance the fish and wildlife habitat by providing hemi-marsh conditions and improving hydrologic circulation (International Great Lakes Levels Board 1973).

FUNCTION OF WETLANDS

Traditionally, these freshwater systems were valued as habitat for migratory waterfowl, furbearers, and coastal-dependent fish stocks. More recently, sport fishing and nonconsumptive recreation, including interpretive nature study and bird watching, have assumed primary importance. A recent study in Michigan revealed that the average economic return values per acre of coastal wetland/year, in descending order, are: sport fishing - \$286, nonconsumptive recreation - \$138, waterfowl hunting - \$31, trapping of furbearers - \$30, and commercial fishing - \$4 (Raphael and Jaworski 1979).

Wetlands provide abiotic values as well, particularly with regard to nonvendable hydrologic values (Table 2). In a small, degraded wetland along western Lake Erie, sediment trapping and nutrient absorption were found to be the most significant functions of this coastal wetland complex (Jaworski and Raphael 1978a). These abiotic functions buffer the littoral zone against water quality and substrate changes and thereby preserve biological functions (Verduin 1969; Great Lakes Fishery Commission 1978). A map of Great Lakes water quality indicates that areas of extensive coastal wetland loss spatially correlate with regions of high littoral eutrophication (International Joint Commission 1978).

FISH HABITAT

Fish communities in the inshore littoral zone tend to be structurally and spatially diverse when compared to offshore pélagic and benthic communities. Wetlands complement the habitat diversity of the littoral environment, while providing areas of primary production and grazing as well as sites for spawning, nursery, and feeding. Historically, individual fish populations exhibited heterozygosity, and most fish species had races of adfluvial and/or wetland-spawning stocks (Smith 1977). Until 1890, when industrial development began to occur, a stock of lake whitefish spawned in Maumee Bay and along the Detroit River (Hartman 1973).

Table 2.--Wetland functions and values, Sterling State Park, Michigan[1]

Function or Value	Current Value	Potential Value
Ground water recharge	Low	Low
Flood control	Low	Low
Coastal protection	Medium	Medium
Sediment trapping	High	High
Nutrient absorption	High	High
Sport fishing	Low	Medium
Commercial fishing	Low	Medium
Fish spawning	Low	Medium
Furbearer trapping	Low	Low
Waterfowl hunting	Low	Medium
Waterfowl breeding	Low	Medium
Waterfowl feeding	Medium	High
Rare and unique species	Medium	High
Nonconsumptive recreation	Low	High

[1] Taken from Jaworski and Raphael 1978a.

At present, species which spawn in the coastal wetlands include northern pike, smallmouth bass, carp, bowfin, channel catfish, bullheads, and several shiners (Jaworski and Raphael 1978b). Many fish feed heavily on amphipods and insect larvae (Mozley 1977), but few coastal wetlands, except for the St. Clair delta, have the requisite hydrology to sustain preferred invertebrate populations. The role of wetlands in providing nutrients for epilimnitic phytoplankton and detritus for detritivores is probably not very significant, except in connecting channels and in Lake St. Clair. Winter kills of carp and painted turtles reflect the rigors of many wetlands during the ice-bound period.

WILDLIFE HABITAT

In contrast to fish communities, wildlife appear to exhibit less direct dependence upon the land-water interface. Nevertheless, approximately 3 million waterfowl annually utilize the Great Lakes shorelines during fall and spring migration for resting and feeding (Great Lakes Basin Commission 1975b). Submersed aquatics in Lake St. Clair and in the Long Point (Ontario) wetlands are important food for divers such as canvasback, lesser scaup, and redhead (Dennis and Chandler 1974). Many coastal wetlands, especially those located near promitories, are part of the migration corridors of songbirds and other avifauna.

Unique bird species, including the yellow-headed blackbird, long-billed wren, black-crowned night heron, and black tern may nest in the Great Lakes coastal wetlands. Piscivorous birds, such as the great blue heron, marsh hawk, and belted kingfisher commonly feed on wetland fauna. With regard to mammals, the furbearing muskrat is ubiquitous, but appears more abundant in cattail marshes. Racoon forage in wetlands, but most other larger mammals, e.g., cottontail rabbit and white-tailed deer, are generally common only along terrestrial margins and during low-water periods. With regard to small mammals, as well as to reptiles and amphibians, less is known about their ecological dependency upon the coastal zone.

LOSS OF HABITAT

Fish habitat is lost when coastal wetlands are developed, degraded, or rendered inacessible due to revetments and dikes. The loss of wetland vegetation diversity, particularly in the backbarrier lagoons, and the successional trend in the coastal fish communities indicate the ecosystem changes. Historically, inshore fish populations consisted, in part, of large-size predator fish such as northern pike, Great Lakes muskellunge, and smallmouth bass, whereas today the abundance of shorter-lived species including carp, channel catfish, bullheads, gizzard shad, and freshwater drum reflect the dominance of fast-growing herbivores and benthic feeders (Great Lakes Fishery Commission 1978; Regier and Hartman 1973).

With regard to wildlife habitat, the loss of the marginal fringe of the wetland as well as water quality deterioration and diking simplifies the ecosystem and reduces habitat diversity. Siltation not only reduces the diversity of aquatic biota and covers spawning substrates with silt, it has recently been found that toxic substances may be accumulating in some wetlands as deposition of allochthonous sediment and particulate organic matter occurs (Neil et al. 1978). Many bird species nest along ecotones (Thobaden 1974), and other wildlife, e.g., meadow-nesting ducks, require the juxtaposition and hydrologic connectivity between several habitat types (Roller and Colwell 1978).

Although some species such as the red-winged blackbird, mallard duck, and muskrat may be selectively favored by diking and reduced habitat diversity, other wildlife such as piscivorous birds, raptors, and diving ducks appear to be adversely impacted. For example, wild celery and other preferred foods of diving ducks are generally not found within diked areas or along highly turbid shorelines. Bioaccumulation of pesticides, human disturbance, and erosion of the wooded barrier islands may be reducing the numbers of marsh hawks and bald eagles which nest along the Ohio coast and elsewhere along the Great Lakes shorelines.

MITIGATION OF HABITAT LOSS

As indicated in Table 3, there are several strategies to mitigate habitat loss. Mitigation not only involves preservation of existing wetland habitats, but should include rehabilitation of degraded wetlands as well as substitution or creation of similar environments which may be located on inland sites (Grabisch 1978). The term restoration implies a direct return to the initial state, including acceptance of previous undesireable characteristics. In contrast, enhancement involves the improvement of the current environmental status by suppressing unwanted features or impacts and by contributing man-made structures to maximize desired functions. When elements of both restoration and enhancement are included, rehabilitation is the appropriate concept (Great Lakes Fishery Commission 1978).

Table 3.--Potential mitigation measures for Great Lakes coastal wetlands

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Preservation of existing wetlands:
- Section 404 and state regulations
- Critical habitat designations
- Public purchase
- Transfer of development rights

Rehabilitation of existing resource base:
- Restoration of upland margin
- Reduction of sediment and nutrient loading
- Removal or modification of hydrological obstacles in fragmented ecosystems

Substitution of replacement ecosystems:
- Offshore islands and adjacent wetlands
- Use of inland sites
- Reliance on artificial stocking programs

Some researchers believe that habitat loss in the Great Lakes is proportional to human population levels and that a practical strategy is to prevent further loss of habitat as growth continues in the future (Great Lakes Fishery Commission 1978). However, given the scarcity of the wetland resource base and recent enactment of specific wetland legislation, future wetland loss will probably be restricted to small, private parcels near previously developed sites. Armed with newly established wetland rating procedures, most Great Lakes states are either purchasing those privately owned wetlands of highest assessed value or are designating selected parcels as environmental areas (critical habitats). A lack of site-specific data, including an understanding of the wetland functions in relationship to the Great Lakes ecosystem, may enable the private sector to challenge such critical habitat designations and evoke the "taking issue".

Enhancement of existing wetland habitat could be accomplished in several ways. First, the shrub-swamp fringe along the upland boundary could be restored; this would allow a continuum of wetland habitats to persist at any Great Lakes water level. Although wildlife may benefit directly by restoration of the upland portion of the environmental gradient, fish communities may also benefit from an improvement in water quality which could result from enhanced sediment trapping and nutrient uptake performed by the green filter belt.

Another enhancement approach involves removal of revetments and earthen dikes as well as modification of hydrological obstacles, including bridges, which prohibit the exchange of water masses and passage of fish and wildlife between the coastal wetlands and the open lake. Approximately 40 percent of the Great Lakes wetlands are diked, and many of these extant ecosystems are fragmented by surface transportation arteries. Drains, highway embankments, and other structures maintained by public agencies may conflict directly with this enhancement strategy.

However, unless the coastal water quality is upgraded, diking of wetlands remains a practical solution to polluted land drainage and extreme lake level fluctuations (Jaworski, Raphael et al. 1979). For example, the diked wetlands of the Erie Shooting and Fishing Club Marsh along western Lake Erie are an island of higher water quality when compared to adjacent wetlands in North Maumee Bay. Implementation of the areawide water quality management plans should effectively mitigate against the subtle but progressive loss of fish and wildlife habitat in coastal wetlands which results from polluted, non-point land drainage.

Other enhancement strategies include carp removal, i.e., to reduce turbidity, especially in diked wetlands, and the stabilization of barrier islands which protect backbarrier wetlands from wave erosion. Local habitat loss may also be compensated by adjacent habitat which functions for a relatively large region. For example, the Bass Island Group in western Lake Erie and the Charity Islands of Saginaw Bay may compensate for loss of habitat along the shorelines by providing functional habitat offshore. Based on the range of adult fish and other ecosystem considerations, it may be possible to determine the minimum distance between functional coastal wetlands.

REHABILITATION OF POINTE MOUILLEE

The largest coastal wetland rehabilitation project in the Great Lakes is the "restoration" of the Pointe Mouillee wetlands of western Lake Erie. During the period 1940 to 1973, approximately 365 hectares of marshland at the mouth of the Huron River were lost to wave erosion (Sellman et al. 1974). At present the U.S. Army Corps of Engineers is constructing a banana-shaped dredged material containment facility along the lakeward margin of this wetland complex. This containment facility will follow the trend of the now eroded barrier island which formerly provided wave protection to the backbarrier marshlands (U.S. Army Corps of Engineers 1974).

In order to rehabilitate the Pointe Mouillee wetland, wave action and turbidity levels must be reduced and water levels lowered so that marsh communities may recolonize the area. Because the State of Michigan, like most other Great Lakes states, had insufficient funds for environmental projects, earlier action to nourish or to stabilize the eroding barrier island of this state game area was not taken. However, by combining the Pointe Mouillee project with construction of a confined disposal facility by the Army Corps of Engineers under Public Law 91-611 and the Resources Development Act of 1976, funds for the wetland rehabilitation were allocated. Once completed, it is surmised that this project will directly benefit dabbling ducks, muskrats, and warmwater fish.

CONCLUSIONS

Because fish may be more dependent on the coastal interface than are most wildlife, mitigation of fish habitat loss should be given priority. An ecosystem approach should be adopted because the Great Lakes fishery has not only been impacted by cultural degradation of fish habitats, but also as a result of selective fishing pressure and introduction of exotic species such as sea lamprey, carp, and coho salmon. With regard to wildlife, waterfowl habitat deficiencies will continue to justify mitigation of habitat losses. However, special attention should be given to enhancement of the submersed aquatic food base of diving ducks, especially in Saginaw Bay, Detroit River and western Lake Erie. If not protected by green filter belts from excessive sediment and nutrient loading, then the coastal wetlands may continue to degrade until they no longer support preferred fish and wildlife communities.

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Mitigating Losses of Private Wetlands: The North Dakota Situation[1]

Keith W. Harmon[2]

Abstract.--No legal means exist to mitigate private drainage of wetlands. To reduce losses the FWS purchases fee or easement interests in North Dakota wetlands. Concern for reaching its 1.0 million acre goal caused the FWS to make concessions in a watershed project that left 30,000 acres of wetlands subject to drainage. As opposition to the wetland program increased, the FWS abolished key positions that provided the only public relations effort for countering the opposition. After six years this situation remains uncorrected.

Under the Fish and Wildlife Coordination Act (16 U.S.C. 661-667e), mitigation traditionally has focused on federal water projects. The Act, however, does not deal with drainage of wetlands undertaken wholly with private capital, or drainage made possible by channels constructed in federally-assisted small watershed projects (16 U.S.C. 1001-1009) and controlled by local sponsors.

Although no precise data exist, intuitively one would conclude that wetland losses in these situations exceed those in projects covered by the Coordination Act.

By 1950 about 50% of the wetlands in two areas had been drained -- lower Mississippi Delta (U.S. Fish and Wildlife Service 1978) and Prairie Pothole Region (Harmon 1971). After another 23 years (1977), only 23% of the Delta bottomland hardwoods remained, and annual drainage rates have been about 5% in Minnesota, 2% in North Dakota, and 1% in South Dakota, with cumulative losses approaching 100% in some local areas.

To protect, rather than mitigate, migratory bird habitat, early efforts commenced with passage of the 1929 Migratory Bird Conservation Act (MBCA) (16 U.S.C. 715-715s), primarily in response to drought. Section 715f required that, "No deed or instrument of conveyance shall be accepted by the Secretary of the Interior ... unless the State in which the area lies shall have consented by law ..." State consent caused few problems in North Dakota, or elsewhere, for a considerable time. North Dakota's Statute 20.1-02-18, enacted in response to Section 715f, simply stated, "North Dakota consents to the United States acquiring ... land or water in this state as the United States may deem necessary to establish migratory bird reservations ..."

The Fish and Wildlife Service (FWS) acquired nearly 200,000 acres of National Wildlife Refuges in North Dakota. Because acreages were concentrated, landowners sought to dispose of their drought stricken land, and approval was not required for each land transaction, the program had a low profile and little opposition. By the time North Dakota's economy recovered, the refuge system was essentially established.

But as times changed and economic pressures on agricultural land increased, drainage became common -- federally assisted and private. To address this situation, Congress passed P.L. 85-585 which amended the 1934 Migratory Bird Hunting Stamp Act (MBHSA). This 1958 amendment authorized the Secretary of Interior to acquire "... small wetland and pothole areas ... without regard to the limitations and requirements of the Migratory Bird Conservation Act..." It also placed all Duck Stamp receipts in the Migratory Bird Conservation Fund (MBCF) for acquisition of Waterfowl Production Areas (WPA) and migratory bird refuges effective July 1, 1960.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 17-19, 1979.

[2] Northcentral Field Representative, Wildlife Management Institute, Firth, Nebraska

Since Duck Stamp sales only generated $4 to $6 million annually, accomplishments were limited. To accelerate wetland protection, P.L. 87-383 was enacted in 1961 which provided a $105 million interest-free loan to the MBCF. Then, beginning in FY 69, 75% of the annual Duck Stamp receipts were to be used to repay the loan. Congress has extended the pay-back period twice -- once to 1976 and recently to 1983. The last extension also increased the loan to $200 million.

Congress, in addition to providing increased funding and authority to protect prairie wetlands, also imposed a constraint that later would become a formidable barrier. The original Act vested approval for acquisition in the "Governor of the State or appropriate agency".

With new authority and funds, the FWS launched a program to acquire 1.75 million acres in Waterfowl Production Areas (600,000 in fee and 1.15 million in easements). North Dakota's share of the WPA goals was 295,000 acres in fee and 775,000 in easements. Keeping the WPA program operational would later affect the FWS's stands on mitigation in small watershed projects.

The WPA program differed from that under which the National Wildlife Refuge System had been acquired. The Governor of North Dakota, finding himself with veto authority, provided the County Boards the opportunity to review and recommend acceptance or rejection of the fee title options. County action was restricted to fee cases since the Governor had given blanket approval to the easement goals. Thus began a constant review of fee options (1,737 as of second quarter, FY79), all by the Governor and some by both he and the counties. The WPA program was in the limelight. Also, drought and depression were dim memories, crops had improved as had income, and land became an asset to retain and expand. To some private landowners, WPA's represented land they had coveted for farm expansion, to County Commissioners they represented land off the tax rolls and weeds, and to still others they were an obstacle to developing North Dakota's agricultural economy. Some just hated the feds. The easement feature likewise became a source of irritation. From the standpoint of practicality and administrative efficiency, easements were described by legal subdivision although the payment and restrictions pertained to the wetlands present. Easements accumulated (11,759 as of second quarter, FY79), making it nearly impossible to plan and/or construct a highway or drainage system without confronting one.

All this aside, there is little evidence that opposition was rampant. In fact, over 13,000 transactions would indicate otherwise. The first identifiable and concerted opposition to the WPA program was in the Devils Lake area. In late 1966, the Chairman of the Sweetwater-Dry Lake Water Management District (WMD) assembled an "ad-hoc" group representing a six county area around Devils Lake to develop resolutions that would lend an air of authority to his personal opposition to the WPA program. The resolutions stated that: 1) the wetland program should be halted where it affected agriculture, 2) waterfowl should be raised artificially, 3) the wetland program should not be extended, and 4) U.S. Department of Agriculture cost-shared drainage should be reinstated. The resolutions were sent to the Secretary of Interior who essentially dismissed them.

The resolutions stemmed from past FWS actions that had prevented the WMD from constructing projects for agricultural drainage. Some years before, the Army Corps of Engineers had conducted a survey of flooding in the Devils Lake subbasin. During the study, the Corps asked the Soil Conservation Service (SCS) to provide data on drainage needs in the basin since any project would not be feasible without drainage. Because of anticipated wetland losses, the FWS and the North Dakota Game and Fish Department opposed the plan. Due to this opposition, and citing a lack of local interest, the Corps suspended further studies. Subsequently, in April 1965, the Sweetwater-Dry Lake WMD and the Chain Lakes WMD passed a resolution that urged the Corps to continue, asked the FWS and the Game and Fish Department to discontinue their opposition, and requested the State Water Commission to hold a public hearing.

With the demise of the Corps' investigation, the WMD resurrected a 1955 application for assistance in the Starkweather Watershed under P.L. 566. In Bismarck (12-16-65) the SCS informed the WMD Chairman that mitigation would be significant. In that regard the Chairman said "We are determined to get a program for drainage -- we have to try to develop wetlands and wildlife along with it." Two months later he canceled the last portion of that statement on local radio by saying, "I don't believe in the leasing and purchase of wetlands by wildlife. I believe wetlands in any community should be developed." Throughout the long and costly negotiations that followed, this posture never varied.

In April 1966 an agency task force filed its mitigation recommendations -- 1) All Type 1's (15,000 acres) and sheet and floodwater were expendable, 2) 85% of all Type 3 wetlands not protected were to be placed under a FWS easement or a 50-year WMD easement, 3) Protection of 75% of the Type 3's was acceptable if the difference, up to 85%, was compensated, 4) All Type 4's and 5's were to be covered by easements, or if destroyed, must be compensated, and 5) Existing FWS easements could be modified with compensation in the interest of project feasibility. While the task force had worked to develop mitigation guidelines, the Chairman of the WMD had requested emergency funds from the State Water Commission to construct a drainage outlet. The WMD rejected the mitigation proposal.

Not to be deterred, the WMD hired a private engineering firm whose proposal was submitted to, and approved by, the State Water Commission in August 1966. In a newspaper article, the Chairman of the WMD stated that project costs were $775,000 and would be paid by local assessments. However the minutes of the Water Commission meeting showed him as saying that 250 miles of channel were needed for drainage at a cost of $8.0 million. He later denied any intention of spending that amount.

Although the Water Commission approved the project, under North Dakota law a project cannot be built if owners of 51% of the taxable value of the land file written protests. By mail the FWS Regional Director informed 144 easement holders that they could not drain land under easement, but could possibly be assessed benefits. He made reference to the $8.0 million. Owners of 59% of the taxable land value protested, stopping the project.

The setbacks suffered by the WMD -- the Corps proposal in 1965, the Starkweather watershed proposal in 1966, and the private drainage plan in 1966 -- all involved the FWS in some way. Passing the resolutions apparently was not adequate retribution. Following the resolutions, the Chairman of the WMD wrote North Dakota's Senator Burdick and accused the FWS's Regional Director of "pure political propaganda in which he took sides on a local political issue" and demanded that he "be reprimanded by the Department for this type of activity, if other proper disciplinary action is not taken." Both Interior and the FWS defended the Regional Director.

Following defeat of the local drainage plan, a FWS-SCS Coordinating Committee met with the WMD (June 1967). In a letter, the FWS's Assistant Director informed Senator Young that "We are optimistic that the project can be planned and developed in the spirit of harmony that prevailed at the Devils Lake meeting." This optimism was not shared by the President of the North Dakota Wildlife Federation who, in a letter to the Regional Director said, "... this Water Management District is interested strictly in drainage and is only giving lip service to any other use." This assessment was well-founded. In an article in The Dakota Scene (Oct. 1967), the Chairman of the WMD outlined his criteria for a harmoniously planned watershed. He suggested that "... if a good waterhole (emphasis added) were developed on each quarter of land, along with tree plantings, then wildlife would have a place." Expanding the criteria, he went on to say, "But to assure these waterholes, the farm land must be drained with excess water flowing into the waterholes to maintain a level that will not dry up during dry years ..." Shortly after the article appeared, the Chairman forwarded to Senator Burdick a petition which opposed acquisition of wetlands by the federal government, asking that it be submitted to any Senate Committee that would be considering wetland legislation.

The Chairman's continuous denouncements of the WPA program were made despite the fact the Starkweather Watershed had been approved for planning (August 1967) and FWS acquisition was needed to achieve mitigation. New mitigation guidelines were proposed by the FWS-SCS Coordinating Committee in February 1968 which made concessions to those the WMD had rejected. They proposed: 1) Preserve all Type 5 wetlands outside the channels, 2) Try to preserve all Type 4's, 3) Substantially compensate Type 4 and 5's destroyed, and 4) Sample 25% of the landowners to determine the acres of Type III's they will preserve (underlining denotes concessions). The FWS Regional Director refused to concur.

After the Regional Director's refusal, the Governor wrote him (3-11-68), stating, "I hope that I do not have to arrive at the conclusion that our wildlife interests are being negative about this matter or are dragging their feet unnecessarily." Three days later the Governor met with the SCS and the FWS. The Regional Director signed the criteria with the stipulation that the criteria were meant to determine 1) the feasibility of a watershed plan from the standpoint of wildlife conservation, and 2) the extent to which landowners would preserve wetlands. Again writing the Regional Director, the Governor said he was "... thrilled and pleased ...", and that "Since you have shown this willingness to cooperate, I hope that ... I can assist you in reaching some of the goals that the wildlife interests seek." Thus WPA goals became a lever to force concessions in the Starkweather

With new wetland inventory data in hand, the Regional Director outlined preservation goals to the WMD and concerned agencies in August. The inventory had identified 18,400 acres of Types 3, 4 and 5 wetlands, of which 15,640 acres (85%) were to be protected by FWS perpetual or WMD 50-year easements. The FWS already had easements on 3,880 acres while the WMD held easements on an additional 413 acres, leaving 11,347 acres to be protected. The Regional Director told the WMD, "... we believe that this ... protection must be provided before the ... Starkweather Watershed is approved."

In March 1969, a meeting was held to review progress thus far. The SCS stated that the project would include 60 miles of channelization at a cost of $3.0 million, which came as a complete surprise to the FWS. The FWS. remained firm on the preservation needs. At the conclusion of agency remarks, the Chairman of the WMD presented his position. He postulated that a 1959 FWS report showed 23,400 acres of wetlands needed for waterfowl in Ramsey County, that this was 3% of the County farmland, that wetlands were equally distributed (an incorrect assumption), and that there were 240,000 acres in the watershed. From this he concluded that protecting 7,200 acres (240,000 x 3%), not 15,640, was their fair share. Still espousing his concept of waterfowl management, and using isolated and unrelated data, he concluded further that since the FWS estimated that 67,000 ducks were produced in the Devils Lake Basin, and since the watershed comprised 16% of the Devils Lake Basin, their share was 10,700 ducks. To maintain that level of production, the WMD proposed to produce 1.1 ducks per acre on the 7,200 acres (7,920 ducks). Also since Dry Lake had 200,000 feet of shoreline and some stock watering ponds reportedly supported a breeding pair per 200 feet of shoreline (U. S. Fish and Wildlife Service 1964), there would be 1,000 breeding pairs using the lake under management and should raise 2000 ducks. He further proposed to dig 150 waterholes that, according to Waterfowl Tomorrow (U. S. Fish and Wildlife Service 1964) would have 2 breeding pairs per dugout and, by his calculations, would produce at least 900 ducks (1 brood of 6 ducks/dugout x 150 dugouts). By mathematical manipulation and the wonder of science, the WMD would raise 10,820 ducks as their share and drain over 11,000 acres of Types 3, 4, and 5 wetlands and all the Type 1's (15,000 acres).

The FWS flatly rejected the proposal of the WMD. When the Chairman asked, "Is this the approach we have to use", the Regional Director said, "Not as far as I am concerned." The meeting concluded with the Chairman informing the FWS that it intended to go to Interior and its Congressional Delegation.

The impass did not terminate efforts to arrive at an acceptable plan. The Governor again applied pressure. Meeting with the Regional Director in May 1969, he indicated that he was considering a moratorium on the wetland program until a solution was reached.

At this point, the impact of the Starkweather project was not restricted to just that watershed. While planning had been underway, the Edmore watershed had been approved for planning (July 1968). The major ditch (Channel A) for the Starkweather had been designed to function as the outlet for the Edmore. Topographically they were one watershed that had been administratively divided to stay within the Small Watershed Act's 250,000 acre limitation. Within the Edmore were 30,000 acres of Type 3, 4 and 5 wetlands, 6,000 of which were under FWS easements.

The next nine months saw endless meetings and letters, Governor's endorsement of the work plan, Governor's refusal to approve 37 fee options, FWS's critical evaluation of the work plan, and attempts by the Chairman of the WMD to have FWS employees who did not agree with him fired or transferred. In November, during a FWS-SCS Coordinating Committee meeting, a FWS representative from Washington posed the question, "How many acres of acquisition with development is needed as an equivalent for 10 acres of easement land?" Although not resolved then, this became the basis for future compromises.

At a January 1970 meeting in Bismarck, after one in Washington between the SCS, FWS and the Chairman of the WMD, a representative of the FWS from Washington stated that the remaining acreage to be protected (5,400 acres) could possibly be reduced by half with wetlands purchased in fee. However the Chairman insiste an agreement had been reached in D.C. that 1 acre of land (wet or dry) in fee would qualify as 2 acres of wetland. The FWS conceded that a tract that had 50% wetland might qualify. The final agreement reached at the meeting also lowered the goals to 13,500 acres (75%) from the 15,640 acres proposed by the FWS in 1968. Although the FWS signed the agreement, the North Dakota Game & Fish Department refused to be a party. The Regional Office directed that easements be emphasized since they represented 1-for-1 credit, but fee purchase with 30 or 40% wetlands would receive 2-for-1 credit. No land was acquired using these criteria because, to purchase a tract with 50% wetlands, metes and bounds purchases were necessary, but unacceptable to potential sellers.

The agreement caused considerable apprehension in the FWS's Devils Lake Wetland Office In commenting the staff wrote, "The criteria will have disastrous effects on the wetland acquisition program, management of fee and easement lands, the drainage referral program, and on other planned or proposed P.L. 566 projects." Their concern did not always remain in-house. In a 1 April 1970 letter to the FWS (D.C.), the Chairman of the WMD asked for disciplinary action and new personnel to work in the Devils Lake area. Shortly thereafter, the Chairman wrote the President saying, "... it is very disconcerting to have employees of the Service publicly continue to reject the attitude of their superiors and oppose the project." Interestingly the Chairman, having been appointed by the Governor to the Citizens Advisory Committee for the Souris-Red-Rainy River Basins Commission, used Basins Commission letterhead to register his complaint. These letters resulted in an official reprimand of a FWS employee, despite the fact he had received the North Dakota Chapter of the Wildlife Society's professional award and was named Conservationist of the Year by the North Dakota Wildlife Federation for stands on Starkweather. Some years later, the reprimand was removed and replaced with a commendation. Two other Wetland Office personnel received reprimands, also withdrawn, for providing acquisition data to the North Dakota Chapter of the Wildlife Society .

In February 1971, progress under the 1-19-70 agreement was reviewed, with another concession being made. The FWS informed the WMD that a Type 4 with 2 acres of upland for each acre of wetland could receive 2-for-1 credit. Likewise a Type 3 within 2 miles of a Type 4 along with 1 acre of upland for each acre of wetland would receive 2-for-1 credit. The following day the Chairman of the WMD appeared before the Legislature and condemned the wetland program. Seven months later he was convicted in federal court for violating a FWS easement covering land he rented for farming. Tried on criminal charges which did not require restorations, the Chairman was fined $500 and placed on 18 months probation. The FWS later requested restoration under civil law with the Court ordering closure of 14 drainage ditches.

While the FWS was operating under the February 1971 criteria, and having moved in additional appraisers, the Chairman of the WMD had directed the County Commissioners to withhold fee approval unless he directed otherwise. Two tracts, containing 1,290 acres, were optioned for which the FWS gave 1,291 acres of wetland credit. There were 280 acres of Types 3 and 4, and although the FWS used the 1971 2-for-1 criteria, it came out as 1-for-1 credit. Consequently the County Commissioners refused to approve the purchase and the Governor implied that he might only approve fee purchase statewide on a 2-for-1 basis, a move that would have reduced fee goals by 25%. Though never done, the Governor again invoked a moritorium on fee options.

Following a meeting with a Washington Interior official, the Governor agreed to approve options for 4,659 acres in the watershed on a 1-for-1 basis. This was, however, 1 acre of land for 1 acre of wetland which was more liberal than the February 1971 criteria but still represented a substantial wetland loss. As a condition, the Governor insisted that, except for negotiations underway outside the watershed, the FWS work only in the Starkweather.

The FWS announced in May 1972, after more than 6 years, that wetland goals had been reached. By modifying the wetland credit criteria twice, and finally abandoning it altogether, the FWS purchased 6,330 acres that contained 992 acres of wetlands (6-to-1 credit). As an example, a 400 acre tract containing 13 acres of wetland was credited as 400 wetland acres (30-to-1 credit). This was the outcome despite the Regional Director's claim in a letter to the FWS Director (7-9-70) that "... recent delineations revealed that few, if any, opportunities existed where wildlife values could be doubled." The net result was 8,517 acres of wetland protected, not 13,500, leaving 5,000 acres in the Starkweather and 24,000 in the Edmore subject to drainage. After the wetland goals were met, the Ramsey County Comissioners resolved to not approve any future acquisition by the FWS.

In reviewing concessions in the Starkweather, a Regional Office staff member commented (7-2-71), "If some environmental group analyzes the Starkweather ... it is going to be difficult if not impossible to defend our actions." That chance came, more by accident than design. The SCS had filed a final Environmental Impact Statement with the Council on Environmental Quality. The Council returned it because it had been filed without agency or public review. Extensive comments were made by national and state conservation organizations, the North Dakota Game and Fish Department, and the FWS -- all critical.

In late 1972, the Secretary of Interior expressed opposition to the project to the Secretary of Agriculture, asking for a reevaluation. In September 1973, the SCS met with the Governor and the WMD regarding such a review. In a letter to Interior, the Secretary of Agriculture said, "Weighing the many, many issues involved and in support of the sponsor's recommendations, we have decided to suspend any further financial or technical assistance to these watersheds." Eight years and thousands of dollars and hours later the Starkweather project (along with the Edmore) was dead -- a project that should have died in infancy.

To this day, the FWS, along with some organizations, is blamed for the defeat of Starkweather, despite endless concessions. Even though Interior's final opposition was the only course, the ramifications of the controversy are evident. In 1975, the Legislature passed a Concurrent Resolution that called for studying the impacts of wetland acquisition on agriculture. The result was Senate Bill 2016, drafted and introduced by the Interim Committee on Agriculture in the 1977 Legislature. The Bill proposed to amend Section 20.1-02-18 of the North Dakota Century Code, the state's consent to acquire land and water for migratory birds in response to Section 715f of the MBCA. It provided that County Commissioners must give their approval before the Secretary of the Interior could acquire land and water in North Dakota. It also required an environmental impact statement from the FWS on each option, along with one on economics by the County Agent for which the FWS would reimburse any costs to the county. Relative to easements, the Bill required that they terminate upon the death of the landowner or upon change of ownership.

Ironically the Chairman of the WMD was elected and served his first term in the North Dakota House during the 1977 session. He actively condemned the FWS wetland program during Senate hearings. He also, along with another representative from the Devils Lake area, sponsored legislation that relaxed drainage permit requirements. The latter was probably academic since they were seldom, if ever, enforced by the Water Commission.

Passage of S.B. 2016 has brought the wetland program to a virtual halt for over two years. With the requirement that an easement expire with the death of the landowner or transfer of ownership, it is impossible to establish payment rates and the FWS has declined to negotiate such easements. In the case of fee, even if the County Commissioners approve an option, the Governor has refused approval under authority of the Loan Act until his demands for Garrison Diversion are met. In November 1978, the FWS set a goal of 10-12 options to be presented to the Governor which were obtained by May 1979. In a letter to FWS staff in North Dakota (5-7-79) the Regional Director instructed that, although approval of the 12 options should be pursued, all current negotiations are suspended.

Some actions have been taken to eliminate the problem. During the 1978 Congress, Representative Dingell introduced legislation to eliminate consenting state legislation and the Governor's veto authority. It passed the House but failed in the Senate. Recently the Department of Justice has filed suit seeking declaratory judgment on the validity of the state law that restricts the terms of an easement. The federal government took 2 years to move. At present, the fate of wetland preservation in North Dakota is in doubt and must be resolved by Congress or the courts.

The FWS made a serious administrative error that needs correcting in North Dakota should Congress and/or the courts reduce state interference, as well as in other acquisition areas to insure that what happened in North Dakota does not happen there. The threat of restrictive legislation in other states is real. In 1979 South Dakota, Montana, and Nebraska considered bills that would have curtailed wetland programs. Except for a Governor's veto, South Dakota would have successfully restricted easements to 20 years. The first options taken to protect coastal marshes in Texas were vetoed by the Governor.

At the peak of opposition in the Devils Lake area, the FWS dismantled the WPA program from a public relations standpoint. Prior to that, it occupied nondivisional status with a Regional Wetland Coordinator reporting directly to the Regional Director whose responsibility was program administration. In North Dakota 3 Wetland Supervisors, located in strategic locations, were responsible for contacts with civic groups, county commissioners, and state legislators. Each Wetland Office had from 1 to 2 Wetland Enhancement Biologists who coordinated with state and federal agencies, local units of government, and landowners on watershed projects, drainage referrals, and legal drains.

Starting in early 1972, a new Regional Director abolished all these positions within a short time, including those in Minnesota and South Dakota. Personal, daily contact with federal, state, and local decision makers terminated when needed most. The WPA program became submerged in a host of other FWS activities -- endangered species, refuges, fish hatcheries, critical habitat, and impact statements. In a field inspection report, a FWS employee commented, "Perhaps the one thing that I noticed the most is the WPA program is not the single minded, unified and attention getting operation it once was." He went on, "The personnel, despite the organization chart, feel disoriented and without the same fervor or attachment to a program that once existed." The need was cited for Wetland Supervisors at the state and regional levels. In an earlier letter (9-26-73) another new Regional Director for Region 3 (Minneapolis) and the Regional Director for Region 6 (Denver) asked for a Wetland Coordinator in Washington.

These pleas have gone unheeded for nearly 6 years, while state opposition mounts wherever the program operates.

The only measure of program success is available funds expended. To be sure, funds are being obligated, but only by shifting them to coastal wetlands and bottomland hardwoods. While these wetlands are important, they are being protected at the expense of prairie wetlands. Unless program administrative changes are made, opposition will result in restrictive state legislation in these areas as well.

One of the FWS's oldest responsibilities, both by international treaty and congressional mandate, is migratory birds, most dependent on wetlands that are being lost at a rapid rate. This responsibility has been placed on the rear burner.

In addition to migratory birds, the FWS has legal responsibilities for assessing the impact of federal projects on fish and wildlife under the FWCA and P.L. 566. These obligations cannot, and will not, be met by the agency if its overriding concern is protecting another program. This is particularly true for programs to protect wetlands where Congress has provided the states with approval authority and where the states have used that authority to force concessions.

In addressing this problem, the FWS must be mindful of several truisms: 1) any adequate mitigation proposal will meet with opposition, 2) where the state has veto authority for one federal program, it will be used to force concessions in another, and 3) any federal program that prevents development of an economic resource will eventually result in some opposition. By ignoring, or at least not recognizing, these facts, the FWS made unacceptable concessions in the Starkweather from the standpoint of North Dakota wetlands and still lost the WPA program. A more logical approach would have been to maintain a firm position on adequate wetland goals in the Starkweather while conducting the WPA program in a manner that would have minimized opposition. Instead the public relations aspect of the WPA program was dismantled at the time opposition reached a peak in both the Devils Lake area and the Governor's office.

In the final analysis, each program should be administered to achieve maximum benefits. But, these outputs cannot be achieved by trade-offs and concessions in one at the expense of the other. They require that each program be conducted with sensitive insight that keeps opposition to each at the lowest possible level. Only in this way can the FWS meet its Congressional and treaty responsibilities.

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Values and Protection of Riparian Ecosystems[1]

Robert J. Behnke[2]

Abstract.--The riparian ecosystem is a zone of highly concentrated values associated with fish, wildlife, recreation, and water quality. Multiple use management on federal lands has often severely degraded riparian zones and associated values. This abuse must be corrected.

INTRODUCTION

Healthy riparian ecosystems have become a vanishing resource in the West particularly in arid and semiarid regions. Historically, many factors have acted to destroy or modify riparian vegetation such as roads, railroads, agriculture and logging. The most pervasive and ubiquitous negative influence however has been and continues to be grazing by domestic livestock. In recent years, an alarm has been sounded by concerned biologists and conservationists to federal agencies to institute better multiple use management of federal lands with a particular objective of restoring and protecting riparian zones and their associated fisheries, wildlife, and recreation values. One result has been several symposia on the values of riparian ecosystems and the threats to their integrity. The proceedings of these symposia edited by Cope (1979), Johnson and McCormick (1979), Johnson and Jones (1977), Menke (1979), and Graul and Bissell (1978) contain abundant data, information, and case histories of riparian significance and values, the factors causing negative impacts, and the feasibility of protection and restoration.

VALUES OF RIPARIAN ECOSYSTEMS

Some values, such as the reduction in numbers and biomass of economically important game fish and game animals attributed to loss of riparian vegetation can be quantified. Other values, associated with nongame animals, esthetics and influence on water quality are more elusive, but nonetheless real.

Winegar (1977) demonstrated the enormously greater diversity and abundance of animals in a fenced riparian zone, protected from livestock, on Camp Creek, Oregon, as compared to the grazed areas along the creek outside the protected zone. Wagner (1978) reviewed the impact of livestock on game animals but without specific reference to riparian vegetation. Destruction of riparian vegetation by livestock can essentially eliminate moose habitat from an area and severely deplete the winter food supply of elk.

At the Sparks, Nevada, livestock, fisheries and wildlife symposium, I (Behnke 1979) reviewed and summarized the evidence from four fishery studies comparing stream sections exposed to livestock with sections protected from livestock. All studies agreed that the protected sections contained three to four fold more trout biomass than the grazed sections. The common denominator in all cases was the presence of vigorous stands of riparian vegetation vs. the destruction of riparian vegetation which resulted in changes in channel morphology.

Several additional case histories of fish loss due to livestock destruction of riparian vegetation and fisheries restoration following riparian protection and restoration are found in Cope (1979). Gregg (1979) demonstrated a strong negative correlation between livestock grazing intensity and trout abundance in several western Colorado streams, and this negative relationship is expressed through impact on riparian vegetation and streambank stability. Van Velson (1979) revealed how Otter Creek, Nebraska, was converted from a silt laden stream inhabited by chubs and suckers into a premier trout stream within a few years after the riparian vegetation was restored by excluding livestock.

In relation to livestock influence on accelerated erosion and water quality, the condition of the riparian vegetation is probably the most sensitive indicator of overall watershed condition. On overgrazed and eroding rangelands, the use and impact on the riparian area is intensified. Thus, in general, there is a relationship between the condition of the riparian vegetation and the rate of accelerated erosion in the watershed. A BLM report on salinity problems in the upper Colorado River basin by Bentley, et al. (1978) identified livestock grazing as the greatest cause of accelerated erosion and associated salt loading of the Colorado River. The costs to downstream water users in the basin are estimated to be more than $330,000 for each additional mg/1 of salt concentration. On the basis of this study, Eggleston and Bentley (1977) calculated that the elimination of livestock grazing from highly erodible public lands would have a benefit-cost ratio of 5.9:1 -- considering only the costs of increased salt concentration to downstream water users. If fisheries, wildlife and recreation losses were to be estimated from watersheds subjected to accelerated erosion, and the loss of downstream reservoir storage to sediment filling were added, the total costs to society caused by past and present grazing systems on highly erodible lands would be enormous in comparison to the benefits of meat production.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

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The magnitude of the problems of the impact of livestock grazing on other natural resource values can be visualized when it is realized that about 48% of the entire land mass of the 11 western states is federal land (mainly BLM and USFS) and that more than 75% of the public land area is grazed by domestic livestock. Federal lands, however, do not produce a significant amount of the total production of cattle and sheep. In the western states, according to 1972 U.S. Department of Agriculture statistics, federal lands produced 19,748,000 AUM's (animal unit months) of a total of 601,917,000 AUM's, or about 3% of the total production of sheep and cattle in the western states.

I believe that utilization of public lands by domestic livestock is a valid use of the lands under multiple use management. However, where present grazing systems continue to have a severe impact on fisheries, wildlife, and accelerated erosion, drastic changes are needed to make grazing compatible with other uses and values. I believe that the condition of riparian vegetation will prove to be the most sensitive and useful indicator of how well revised grazing systems are working to make them compatible with the objectives of multiple use management.

LIVESTOCK IMPACTS

The loss of terrestrial animals from the destruction of riparian vegetation is a straightforward situation -- the essential habitat is eliminated. Damage to aquatic ecosystems is by indrect means. Riparian vegetation provides streambank stability, shading, and cover. The loss of riparian vegetation destabilizes the banks and warms the water. Typically, grazing intensities that eliminate riparian vegetation also overgraze the watershed so that precipitation from intense rain runs overland and is not sufficiently retarded by vegetation and absorbed by the soil. This, in turn, greatly increases the the amplitude of flood peaks and sediment loads. The destabilized streambanks cannot contain the energy of high flows and, depending on the substrate, will either break down and braid out or trench down into an arroyo. Either alternative results in shallow, high velocity flows lacking adequate cover or suitable habitat for fish. The result is a crash or elimination of a trout population. The seasonal flows now change to a regime characterized by a brief period of high, silt laden flows during the wet months or after storms, followed by low or intermittant flows the rest of the year.

How many millions of pounds of trout, salmon and other game fish are lost each year on federal lands because of riparian degradation causing streams to produce below their natural carrying capacity can only be guessed. Estimates are also lacking on the numbers of game and nongame animals that could be increased if riparian ecosystems were restored to natural conditions along thousands of miles of streams.

The negative impact of livestock on riparian vegetation is not evenly distributed. In higher elevations with high levels of precipitation and good distribution of water and forage, the impact is generally light. It is the arid and semiarid regions with less than 20 in. (500 mm) annual precipitation and long grazing seasons that are particularly susc-ptible to destruction of riparian vegetation because livestock tend to concentrate along streams in the dry months. In the arid and semiarid foothills and plains regions the structure and diversity of riparian vegetation is of paramount importance for the abundance and diversity of terrestrial wildlife.

PROBLEMS AND SOLUTIONS

Millions of acres of arid and semiarid grasslands and riparian ecosystems in the Southwest were essentially destroyed by overgrazing during the time of the open range and converted to arroyo gutted landscapes characterized by xeric types of vegetation of little value even to livestock. In most regions of the west the arid and semiarid public lands are administered by the Bureau of Land Management. Since the days of the Grazing

Service, the predecessor organization of the BLM, this agency has been oriented to and dominated by livestock interests. Encouraging changes are taking place, but it is a long and tortuous route between high sounding policy statements on the objectives of multiple use land management emanating from Washington through various state and regional administrative layers to interpretation and implementation on the land.

If real progress is to be made, it is imperative that better communications become established between field biologists with the understanding and know-how and decision makers. For example, in a 1977 Task Force Report on forest, range, wildlife and fisheries habitat development, to the Regional and National Agricultural Research Planning and Implementation System (WRPC-RPG-2), I note statements such as: "The effects of wild and domestic grazing animals on fisheries have not been adequately measured." . . . "Although grazing by livestock and wildlife is widespread and impinges on nearly every stream and lake in the Western United States, the effects of grazing on aquatic ecosystems are virtually unknown." I would point out that sufficient knowledge and data are available on the effects of grazing on wildlife and fisheries to establish common cause and effect relationships and to implement corrective action. The papers presented in the symposia cited previously, many written by federal biologists based on studies on public lands, are abundant evidence of what is known. If the Task Force members really believe that wild grazing animals are a serious problem to aquatic ecosystems I would suggest a visit to Yellowstone or Rocky Mountain National Parks where maximum abundance of big game animals occur and to observe the condition of riparian vegetation, aquatic ecosystems and the quality of the fisheries. I would also suggest observations of the numerous long term exclosure studies on USFS and BLM lands where livestock, but not wild animals, are excluded and examine the impacts of wild animals. The danger is that there tends to be a reflex response to a crisis situation by initiating more "research," without asking the questions in need of answers. When this occurs, such research often is focused on phenomena not directly involved with cause-effect relationships and is useless for providing problem solving answers.

As a contribution toward more rapid resolution of the conflicts of livestock grazing with multiple use management on public lands, and to clarify the issues involved, I emphasize an undersatanding of the following points:

1. Domestic livestock can and do cause severe damage to riparian vegetation which, in turn, has a negative impact on fish, wildlife, and recreation values. There is no need to further "prove" that the negative impact occurs, but only to begin to identify the allotments where damage occurs and to quantify the extent of the damage with the subsequent loss of multiple use values.

2. Riparian vegetation can rapidly recover in from one to five years after it is protected from livestock grazing.

3. No amount of research on terrestrial or aquatic biology can provide solutions to the grazing problem. The problem, where it exists, can only be solved by preventing livestock from congregating along streams. Presentl no grazing system has been demonstrated effective in protecting riparian vegetation. This is a range management problem and the highest priority must be given to the development of new grazing management systems where the present system results in riparian degradation.

4. There has not been significant improvement of the arid and semiarid western range on BLM lands since the Taylor Grazing Act of 1934. A 1975 BLM range condition report prepared for the U.S. Senate Committee on Appropriations, states that 83% of the range is in less than satisfactory (less than excellent or good) condition. In the long term, it is the livestock operators who have the most to gain from better management of the western range designed to stabilize the land and increase forage production.

It is obvious that because watersheds occur on both public and private lands, comprehensive rehabilitation projects must involve cooperative efforts of the USFS and the BLM on public lands and the Soil Conservation Service on private lands. Innovative grazing systems must be tried to find those best suited to avoid destruction of riparian vegetation. In many situations fencing will be required. In severely degraded areas, the cessation of livestock grazing for five years or more or perhaps permanently will be necessary to restore the natural vegetation and restore other natural resource values. In such cases, the financial burden imposed on livestock operators could be mitigated by a subsidy for the loss of AUM's from federal lands being rehabilitated.

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Monitoring, Maintenance, Rehabilitation and Enhancement of Critical Whooping Crane Habitat, Platte River, Nebraska[1]

John G. Aronson[2] and Scott L. Ellis[3]

Abstract. In May, 1978 the U.S. Fish and Wildlife Service designated a portion of the Platte River from Lexington to Denman, Nebraska as critical habitat for the whooping crane. Changes in the flow regime of the Platte River have resulted in modification of the "pristine" riverine habitat, especially with respect to increasing vegetative encroachment on channel islands and decreasing wet meadow habitat. Desirable whooping crane roosting and feeding habitats have been adversely affected by vegetative encroachment, and by decreasing groundwater levels, respectively. This paper explores the process of vegetative succession on Platte River islands, compares various river stretches on the basis of vegetative change (1938-1969), and discusses the potential for monitoring, maintaining, rehabilitating, and enhancing critical whooping crane habitat as means to mitigate future natural and/or man-made changes in the Platte River flow regime.[4]

INTRODUCTION AND HISTORICAL PERSPECTIVE

The Platte River system in Nebraska (fig. 1) has been subjected to manipulation by man since early settlers first began to divert water from its natural watercourse. Since the turn of the century, increasing demands upon the system have caused a significant decline in the natural flow reaching the "Big Bend" area of the Platte River in south-central Nebraska. Throughout most of its length in western and central Nebraska, numerous sandbar islands create an intricately braided stream. Decreases in annual peak and mean discharges (fig. 2-4) hav allowed vegetation to establish within th main channel on the sandbar islands where onc higher flows scoured the islands and effectively controlled vegetational succession Today the Platte River in the "Big Bend" area is a series of small channels which meande through large stands of herbaceous and wood vegetation on various sized sandbar islands Williams (1978) has documented the shrinkag of channel width, decrease in flows, an relative vegetative encroachment within th Platte River system. Most areas along th river have changed dramatically over the pas 70-100 years, while a few areas have remaine relatively stable over this period (Frit 1974).

The "Big Bend" area is an extremel important natural resource, especially wit respect to wildlife values. Bald eagles ducks, geese, sandhill cranes, whoopin cranes, and many other important specie utilize the central Platte River valley.

When vegetation is established within th main channel on sandbar islands and is left t proceed through normal successional stages the vegetation achieves a height at which th sandbar island habitat is considered unusabl for in-channel night roosting by whoopin cranes (*Grus americana*) or sandhill crane (*Grus canadensis*) (Frith 1974). These bird utilize the "Big Bend" area of the Platte

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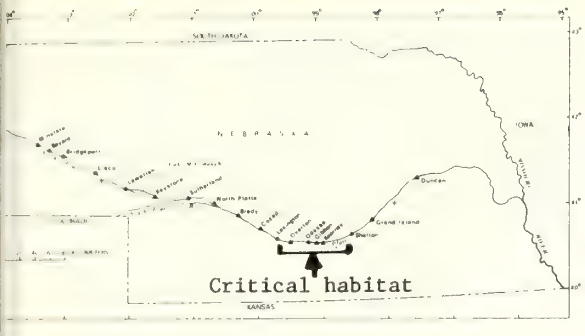
[4] Acknowledgements for their assistance go to Bob Wicht, National Audubon Society; Charles Frith, U.S. Fish and Wildlife Service; Kearney State College; and Basin Electric Power Cooperative.



igure 1. Platte River study area (after Williams 1978).

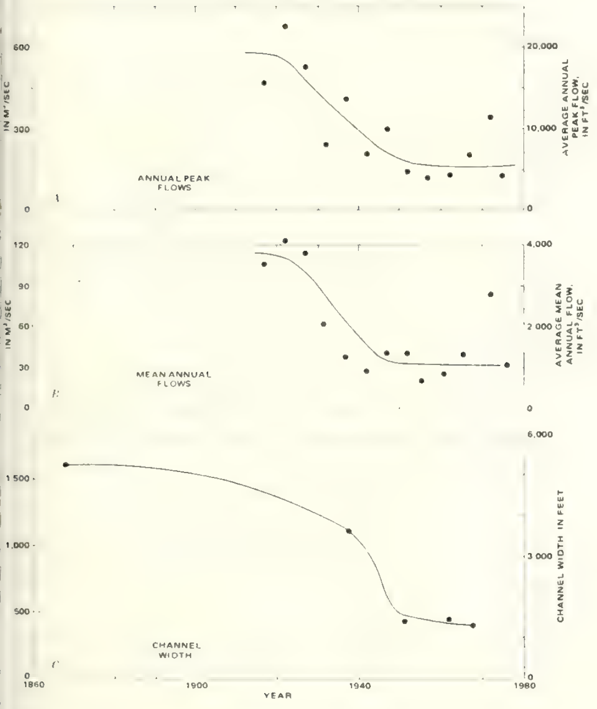


Figure 2. Historical trends of annual peak flows, mean annual flows and channel width, Platte River near Overton (after Williams 1978).

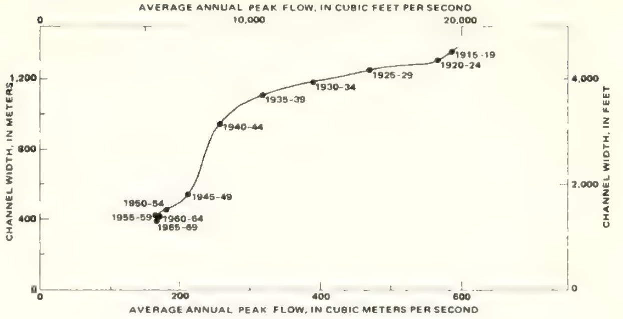


Figure 3. Relation of channel width to 5-year-averaged annual peak flows, Platte River near Overton (after Williams 1978).

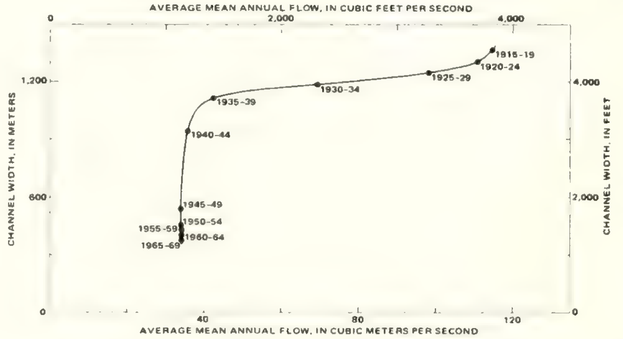


Figure 4. Relation of channel width to 5-year-averaged mean annual flows, Platte River near Overton (Williams 1978).

River in the spring months (late February to early May) as a staging area and in the fall months as a stopover point during their normal migratory flights between their overwintering grounds in southern North America and their breeding grounds in Canada. Wetland habitats (wet meadows) adjacent to the river are considered important feeding areas for cranes (Frith 1974). These wet meadows are intimately linked to the Platte River hydrological system. (Keech 1964). Thus, changes in river level are reflected in the groundwater levels of wet meadow habitats.

In May, 1978 the U.S. Fish and Wildlife Service (FWS), designated the area of the Platte River from Lexington to Denman, Nebraska (about 53 river miles) as critical habitat for the threatened and endangered whooping crane

(Federal Register, Vol. 43(94)-May 1978). Thus it is important to ensure that no destruction or modification of this critical habitat occurs, either in the river channel itself or in the wetlands (wet meadows) immediately adjacent to the river.

Figure 5. Whooping cranes at overwintering habitat, Aransas, Texas.

In September 1977, a research program concerning the Platte River in Nebraska was undertaken by ERT/Ecology Consultants, Inc. to study various parameters including flow, fisheries, wildlife, vegetation, water quality, and migratory waterfowl utilization (including whooping and sandhill cranes). Effort was concentrated in the critical habitat area, with emphasis upon the stretch from Overton to Gibbon, Nebraska.

Beginning in the spring of 1977, and continuing through winter 1978, quarterly aerial reconnaissance using color infrared photography techniques was conducted. In the summer of 1978, specific field investigations of vegetative succession and encroachment were performed to determine the basic characteristics of the vegetated islands occurring in the Platte River. Based upon these investigations, data were collected on the status of vegetational encroachment in the main channel and on the successional sequences that take place during this process.

Comparisons of aerial photographs taken in 1938 with those from 1969 and 1976 were conducted separately by the FWS and by ERT/Ecology Consultants, Inc. Results of both studies indicated that the response t upstream and instream flow depletions ha varied, depending upon location. However there is no doubt that there has been degradation of usable crane habitat in som locations, and the evidence strongly suggest that the decline in flow has reduced th natural scouring which once kept vegetativ encroachment from becoming well establishe within the main channel.

As a result of degradation that ha occurred to the Platte River crane habitat three general classes of crane habitat hav been identified: pristine, transitional, an degraded (Frith 1974). This classificatio was based upon the amount of loss in ope habitats (open water plus low herbaceou vegetated sandbar islands). Based upon th 1938-1969 comparison, degraded crane habita was characterized by losses in open habitat o about 80%. Transitional classification wa divided into low order and high order. Lo order transitional areas were represented by loss in open habitat very close to degrade (60-75%). High order transitional area experienced losses of about 30-50%. Pristin areas exhibited loss of open habitat of 20% o less.

Within the stretch of Platte River designated as critical whooping crane habitat, al three types of areas occur in various places Evaluation of river channel shrinkage dat coupled with analysis of comparative aeria photography indicated those areas that exhibited the narrowest channels (historically) today exhibit the least amount of vegetativ encroachment. This tends to support th concept that the annual scouring of the channe islands is an important factor for controllin crane habitat degradation. Generally speaking in areas where the river channel is wide flows have not been able to keep vegetatio scoured. Where channels have been narrow even recent flows have been able to kee islands scoured.

Wet meadows have also been affected b decreasing stream flow. Since the Platt River flow level is a reflection of alluvia groundwater level and vice versa (Keech 1964) wet meadows that do not receive adequat subirrigation are converted to cultivate land. Higher water levels prevent loca farmers from converting wet meadows to field of small grains and row crops.

In light of the increasing demand fo agricultural, municipal and industrial use o Platte River water (utilizing both on-stream version and ground water pumping), mainte- nce of desirable crane habitat, namely, ght roosting areas and wet meadow areas for eding, is of increasing importance and ncern.

The basic problem of habitat degra- tion due to decreasing flow is complicated several other factors:

- Water rights and appropriations, interstate and intrastate
- Operational constraints of irrigators
- Variable precipitation in the basin
- Use of vegetated islands by other important species such as eagles, deer, herons, etc.
- Increasing economic pressure to convert wet meadows to cultivated land.

With such a number of powerful forces rking against maintenance of critical ooping crane habitat, it appears at this me that more positive measures will need be employed in order to maintain the atus quo. Indeed, recommendations by the S (1977), Frith (1974), Wicht (1979) and T (1978) indicate that much needs to be ne in the way of habitat maintenance, habilitation, and enhancement in the near rm to prevent a deterioration of existing nditions.

The primary purposes of this paper are elucidate the current status of the itical habitat area, to describe the ocess of vegetative encroachment on Platte ver sandbar islands, and to explore various tential monitoring, maintenance, rehabili- tion, and enhancement measures to be used mitigate impact to the critical habitat ea by future man-made and/or natural flow pletions within the Platte River system.

VEGETATIVE SUCCESSION AND ENCROACHMENT

Studies of plant succession in flood- ains of the Mississippi River system ikman 1926, Wilson 1970, Lindsey et al. 61, Peterson 1957, Shelford 1954, Weaver 60) demonstrate that a universal primary ccessional sequence occurs on shorelines d islands of frequently flooded rivers. is sequence consists of initial coloniza- on of barren sandbars by herbaceous annual d perennial plants and by seedlings of eastern cottonwood and various willow species. Willow saplings begin to stabilize the sandbars by extending lateral roots which bind the soil. Willows predominate on the sandbars until cottonwoods attain sufficient size to shade the willows. Since willows are intolerant of shade, they begin to decline. In turn, cottonwoods begin to decline after 30 to 40 years because cottonwood seedlings cannot survive in the shade of the parent trees. More shade-tolerant trees such as American elm, green ash, mulberry and box elder constitute the climax plant community in much of the lower Platte System.

The predominant process affecting vegetation succession on the Platte River islands is continuing disturbance due to river action (flooding and ice scouring) and man's efforts to clear islands and shorelines using fire and mechanical methods. These factors have accelerated or reversed the successional process intermittently and incompletely across the floodplain. As a consequence, all stages of succession occur simultaneously within the same river reach.

Remote sensing studies support the contention of Frith (1974) and Williams (1978) that woody vegetation has encroached on the river channel over the last 40 years, reducing the width of the channel and reducing the area of sandbars and low islands used by cranes.

In some areas, loss in area of the main channel was estimated to be 70%. In areas classified as transitional or degraded crane habitat (Frith 1974), the loss of open habitat ranges from approximately 40 to 80%. In the one pristine habitat sampled, there was a main channel loss of 30%, but loss of open habitat of only 27%. Shifts in vegetation classes were not consistent among transects. There was a general increase in area of tree-dominated islands between 1938 and 1969, but some declines also occurred. Tall shrub islands also showed variable shifts in acreage between 1938 and 1969, but changes were not large as compared to changes in tree and sandbar habitat.

Table 1 presents a successional sequence which may be expected through a period of approximately 40 years within the area studied on the Platte River. Approximately the first 15 years of this cycle are of primary interest in determining the availability of crane habitat. The overlap in time among the different stages accounts for differing degrees of exposure to disturbance factors over time. For example, an island may persist in the low shrub stage for ten years (and perhaps indefinitely) if it is subject to annual river scouring. On the other hand, an island may contain shrubs ten feet tall and young trees 20 feet tall within ten years after establishment if the stand is protected from scouring and other disturbance factors.

Table 1. Vegetation succession on Platte River isalnds near Kearney, Nebraska.

Years	Height (feet)	Species Composition
0	0	gravel and sand
1	1-2	cocklebur, ragweed (mesic), white clover (xeric)
2-3	2-3	willow and cottonwood seedlings, cocklebur
4-9	3-6	willow, indigo bush (low stage, subject to frequent scouring)
10-15	7-12	willow, indigo bush, tree saplings (tall stage)
10-20	tree: 15-20 shrub: 10-15	willow, indigo bush, red dogwood, tree saplings
20-30	tree: 20-40 shrub: 10-15	young cottonwood and juniper trees, red dogwood
30-40	tree: 40-60 shrub: 10-15	mature cottonwood, juniper, American elm, red dogwood

The following section discusses different successional stages observed on Platte River Islands. Dominant plant species and river vegetation interactions are discussed for each major stage.

Herb-Dominated Islands (Early Succession)

The herb-dominated islands consist primarily of annual species (cocklebur, ragweed, toad rush) which establish themselves each year on sandbars after the spring runoff recedes. Hadenfeldt (1978) found that cocklebur had the highest importance value among herbaceous species sampled on islands in the vicinity of Kearney. These species are successful because they produce large numbers of seeds, and the river disperses these seeds over a wide area (Lindsey et al. 1961). Annual species als germinate quickly to take advantage o available moisture, or develop a long taproot (cocklebur) to take advantage of deeper soi moisture. Plant canopy cover was estimate to be extensive (75 to 100%), and maximu average plant height in July was approxi-mately 3 feet.

Included on herbaceous islands ar scattered willow and eastern cottonwood plant which attained the same height as the surround-ing herbaceous vegetation. Excavation o these woody species indicated that nearly al of these plants were sprouts from old (5-1 years) woody crowns. A similar observatio was made by Walters (1978) on islands in th same area. At the same time thousands o cottonwood and willow seedlings were observe on bare sand in the channel adjacent t islands. These seedlings matured from seed deposited on the bare sand during late sprin 1978. These two observations taken togethe (numerous current-year seedlings, old roo systems) suggest that there is almost complet mortality of each annual willow and cottonwoo seedling crop either by drying of the channe bed or by scouring by spring runoff flows, ar that sprouts from the occasional survivors ar buried or sheared off annually by flooding ice. Lindsey et al. (1961) found that "acti of ice accompanying more usual stream level damages the low growing *Salix interior* chronically that this is a highly unstab woody plant community".

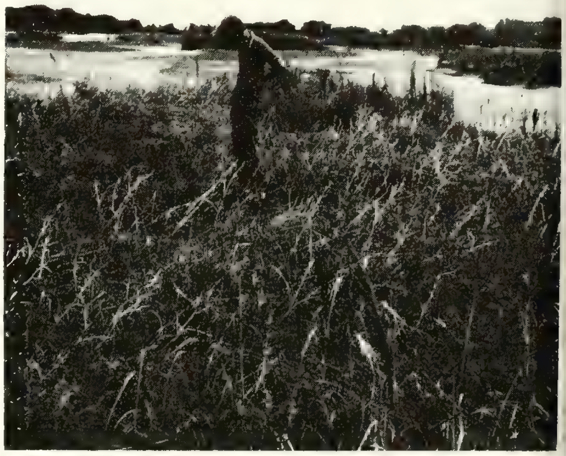


Figure 6. Platte River island - ea successional stage.

Shrub-Dominated Islands
(Intermediate Succession)

The capacity of willow species to tabilize sandbars and river channel banks as been documented for several river systems Wilson 1970, Lindsey et al. 1961, and eaver 1961). Willows extend shoots from hallow, widely branching root systems. illows are also capable of layering (rooting rom nodes on buried stems) (Lindsey et al. 961). The thickets that arise from these oot systems trap additional sand and silt, nd raise the level of the island. Willows an resprout when buried at least three feet nder deposited sediment (Peterson 1957). his characteristic enables these plants to ersist under conditions of rapidly fluctuting substrate depth caused by variable iver sediment deposition patterns. The apacity to resprout is an important adapive characteristic to survive frequent evere injury from floods and ice.

Sandbar willow and false indigo domiate the early stages of shrubby islands in he Platte River. Shrubs usually range in eight from 5 to 7 feet, and provide approxiately 30% canopy cover. Most shrub stems verage from 4 to 7 years old.

As islands mature there is a transition rom low shrub to tall shrub islands conaining young trees. The primary composiional change is the increasing importance f shade-tolerant red dogwood in the shrub tratum, and the appearance of a tree stratum, greater than 15 feet) consisting of eastern ottonwood, American elm and green ash. A orizontal stratification of woody species ecomes evident as the island matures. alters (1978) found that sandbar willow, eachleaf willow, diamond willow, false ndigo and elderberry occurred over 50% of he time on the island edge; eastern redEdar, red dogwood, green ash, slippery elm, merican elm and viburnum occurred 50% of he time in the center. These data suggest hat the more flood-tolerant and shadentolerant species occur on the island erimeter. Cottonwoods were also found to ncrease in number at the island center over ime, which may be a consequence of proection from floods and ice.

Walters (1978) determined composition oefficients of similarity for the different ges and sizes of islands studied. She ound a high degree of compositional simiarity (all coefficients 0.80 or above) mong the islands regardless of size and age. These data suggest that a large fraction of the woody species establish themselves early in the history of the island, and then different species groups assume dominance depending upon the degree of disturbance suffered by particular islands.

Maximum age of shrub stems on the tall shrub islands ranged from 10 to 15 years. It appears that 15 years may be near the maximum stem age for these species since standing dead stems were frequently seen. Because new shoots are constantly arising from root systems of these species, shrub thickets are maintained for much longer periods than the maximum age of individual stems.

Tree species sampled from the tall shrub islands demonstrate a capacity to grow to a height of approximately 20 feet in 10 years. Other studies indicate that cottonwood can grow very quickly. Peterson (1957) found that cottonwoods grew 18 feet in four years along a reservoir margin in southwestern Nebraska; Lindsey et al. (1961) reported a cottonwood on the Wabash River in Indiana that grew 40 feet in 14 years.

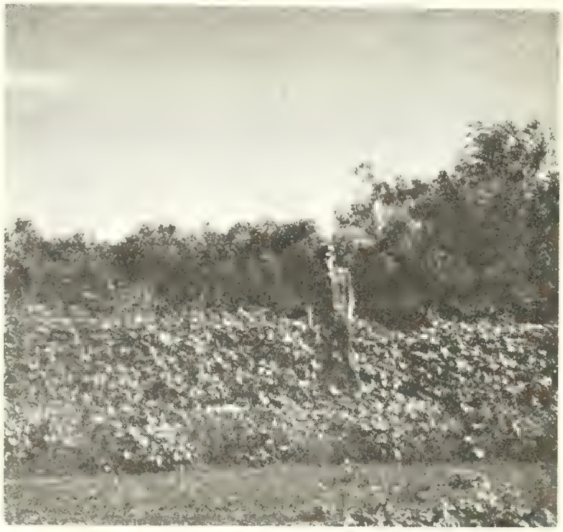


Figure 7. Platte River island - shrub dominated successional stage.

Tree and Shrub-Dominated Islands
(Late Succession)

The oldest successional stage in the Platte River near Kearney consists of an overstory of eastern cottonwood estimated from 40 to 60 feet tall and a shrub stratum 10-12 feet tall consisting primarily of red dogwood.

Combined shrub and tree canopy was estimated to be in excess of 100%. Eastern cottonwood tree age was estimated to be between 27 and 51 years.

False indigo and sandbar willow were scarce to absent in these stands, indicating that these intolerant shrubs had been shaded out. Red dogwood maximum age was 19 years, and showed no evidence of dying out. Young eastern redcedar, green ash and American elm were recorded, indicating that these stands have not proceeded to the regional climax consisting primarily of green ash and American elm.

Tree age data suggest that cottonwood establishment occurred primarily in the last 30 to 40 years, coinciding with the closure of Kingsley Dam upstream.

Table 2. Plant species discussed in the text.

Common Name	Species Name
Trees	
American elm	Ulmus americana
Boxelder	Acer negundo
Eastern cottonwood	Populus deltoides
Eastern redcedar	Juniperus virginiana
Green ash	Fraxinum pennsylvanica
Mulberry	Morus rubra
Peachleaf willow	Salix amygdaloides
Slippery elm	Ulmus rubra
Shrubs	
Diamond willow	Salix eriocephala
Elderberry	Sambucus canadensis
False indigo	Amorpha fruticosa
Red dogwood	Cornus stolonifera
Sandbar willow	Salix exigua ssp. interior
Viburnum	Viburnum edule
Herbaceous	
Cocklebur	Xanthium strumarius
Prairie cordgrass	Spartina pectinata
Ragweed	Ambrosia sp.
Toad rush	Juncus bufonius

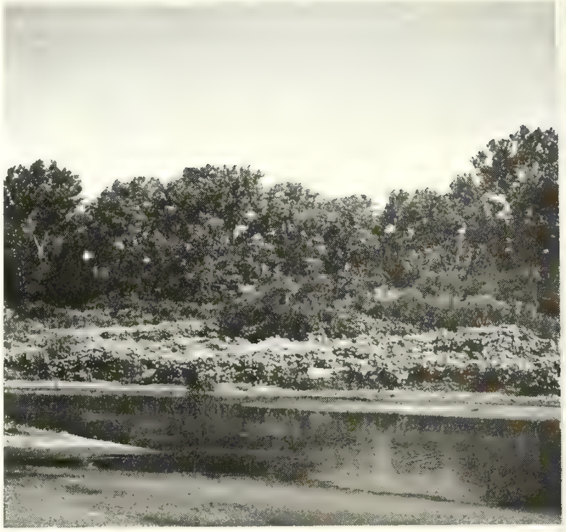


Figure 8. Platte River island - late successional stage.

WET MEADOW CONSIDERATIONS

Wet meadow habitats, important areas f crane feeding, have also been affected b declining Platte River flows. Recent investigations by the FWS indicate that certai critical food items which are high in protei may be important in the diet of sandhil cranes (Krapu 1978), and that wet meadows ne the Platte River supply the bulk of this ty of food. Due to the hydraulic connecti between groundwater level and Platte Riv flow (Keech 1964), wet meadow habitats depe largely upon water within the alluvial syste Upstream depletions and local groundwat pumping for irrigation combine with th naturally occurring summer decrease in riv flow to produce a severe drying effect up wet meadows. Groundwater recharge from irr gation return flows is seen as evidence f the linkage between river flow, vegetati encroachment, and wet meadow deterioration certain stretches of the Platte River.

When, within the annual hydrologic cycle, wet meadows no longer receive adequat moisture, local farmers often convert thes areas to cultivated land. There exist fir today which are willing to drain, grade, a tile wet meadows for conversion to cropland.

According to Frith (1974), sandhi cranes prefer wet meadow complexes for feedi in early spring, usually until mid-March. He believes that as the wet meadow food sources become exhausted, the cranes seek alternate food items in croplands. Although cranes are quite omnivorous, whether or not croplands alone could maintain the physiological well-being of the populations is unknown. Reinecke and Krapu (1978) do not believe croplands alone could support cranes, because of differences in food items taken in different areas. With respect to whooping cranes specifically, practically nothing is known about their food habits within the Platte River critical habitat area. Allen (1952) indicates that animal food items may be more important in the diet of the whooping crane, than for the sandhill crane.

All evidence suggests that wet meadow habitats protected from human disturbance represent an important component of the total habitat for sandhill cranes and whooping cranes. Thus, efforts should be taken to maintain, rehabilitate and enhance these habitats whenever possible.

HABITAT MONITORING

The importance of implementing sensitive habitat monitoring techniques which are capable of identifying changes in vegetative encroachment and wet meadow status within the critical habitat area cannot be overemphasized. A sound habitat management plan must rely upon an understanding of past history as well as current processes to be able to be responsive to the needs of the habitat, and ultimately to the needs of the species occurring in that habitat. Three important elements of the critical habitat area can be identified for monitoring:

a) Hydrology - surface and groundwater

b) Vegetative encroachment - areal extent and height

c) Wet meadows - areal extent and food supply.

Hydrological concerns, both surface and groundwater, are currently monitored by the USGS at several locations within the Platte River system. A coordinated effort is needed to tie together the surface and groundwater regimes to gain an understanding of the hydraulic connection between the two. Substantial historic river flow and groundwater data currently exist and will continue to be monitored for year to year comparisons.

Vegetative encroachment and wet meadows could both be monitored effectively and efficiently using existing aerial photography techniques. Complete black and white aerial coverage of the critical habitat area is available for several years since 1938. It is suggested that reliance be placed upon stereo color-infrared aerial imagery at a scale of 1:4800 (1 inch = 400 feet) or less. Sufficient vertical exaggeration is required to be able to delineate between vegetation that is less than 18" and that which is greater than 48" to determine useful and non-useful crane roosting habitat, respectively. Sufficient coverage would be required to photograph a corridor 3 miles wide centered on the main channel. The optimal time to photograph the system would be during the summer months when flow is least and vegetative growth is maximum. The monitoring of vegetative change in this manner could use spring imagery of crane roosts in a comparative process to relate habitat use and habitat status from the previous year. Locations of important crane roosts would be analyzed carefully for vegetative change. This would help to identify desirable habitat characteristics which could be used in habitat management during the summer preceding each spring migration period. In this way, preparation could be made each summer for the next high crane use period the following spring.

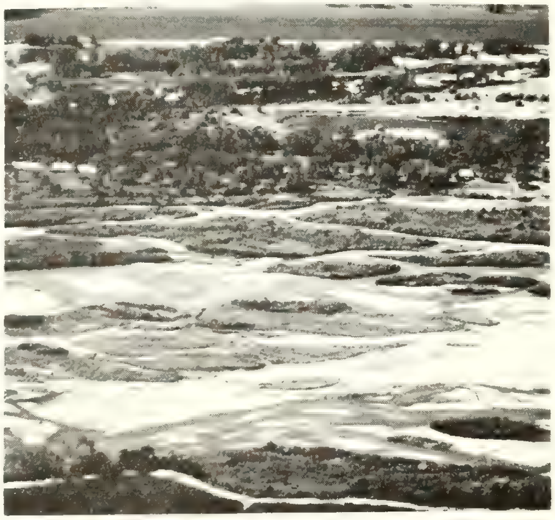


Figure 9. Color infra-red aerial photograph of critical whooping crane habitat - oblique view near Kearney.

Interpretation of the photographs would consist of identifying islands and wetlands occuring in the Platte River. Islands would be divided into three categories:

- Category I - Open sandbar and low annual herbaceous vegetation; considered very desirable crane habitat.

- Category II - Transitional shrub vegetation; consisting of shrub saplings and seedlings ranging from 2 to 4 feet in height and considered marginal for crane habitat.

- Category III - Tall shrub and tree vegetation; consisting of shrubs and trees in excess of 4 feet in height - unusable for crane habitat.

All available wetland areas would be identified. The structural classifications obtained by photo-interpretation could be confirmed using ground-based surveys within the actual habitats to verify the height of vegetation and vegetation density on the islands, to assess the degree of natural scouring, and to assess the effectiveness of various habitat management techniques (as discussed below). Wetlands would be checked from year to year for areal coverage. Again, photo documentation would be used to establish trend data on the height of island vegetation. Islands would be photographed at the midpoint of their longitudinal and transverse axes to provide a record of their classification. Each island could be numbered during photointerpretation and crosschecked in the field. Photography and standard survey techniques could be implemented at standard river locations such as important crane roosts, sites of transitional islands, areas of disturbance, experimental management areas, refuges, etc. It is anticipated that this process could be completed within one growing season so that subsequent vegetative change could be compared on an annual basis. All areas of the island classes, open channels, and wetland habitat would be computed using standard dot grid or digitizing methods and used for future comparisons.

Photography taken in subsequent years would then be interpreted using the same classification criteria used during the first year. The emphasis of this analysis would be to define transitional islands which might become undesirable as crane habitat and to document changes in areal extent of wetland habitat. The purpose of each year's interpretation would be to determine the acreage within the transitional class so an assessment can be made as to the extent of habitat degradation or improvement from year to year.

Major vegetative changes of bare or early stage succession islands (as related to crane habitat) should not appear until after three growing seasons have passed (the time required for riparian shrub species to grow from seedlings to about 4 feet tall). Extent of vegetation cover within the river channel should be compared with baseline vegetation cover to determine increases or decreases in transitional islands and wetland habitat. All areas interpreted as transitional should be field checked each year and identified for maintenance.

It is anticipated that any potential effects to wetland habitats would be related to agricultural conversion following two or more dry periods in the wet meadow. Thus, a record of annual flow must be established using a statistical base for correlation with loss of crane habitat. Each year, annual flow could be averaged for all U.S. Geological Survey gaging stations occurring in the critical habitat area (Lexington to Denman). A statistical analysis of past flows could be performed to establish a reasonable mean base flow along with its variation (standard deviation). By comparing annual data on river flow with the historic levels, it should be possible to predict effects on crane habitat with some degree of reliability. For years with a flow higher than the base flow, little habitat maintenance should be required for a period at least three years hence. However, continued monitoring should be performed, and habitat maintenance could be recommended for those islands which do not respond to the scouring action of these higher flows.

During lower-than-normal base flow years, maintenance of habitat would probably be required due to the rapid growth of the vegetation.

MAINTENANCE, REHABILITATION AND ENHANCEMENT

In this paper, maintenance refers to the continued preservation of current conditions. Rehabilitation refers to the process of returning habitat to a previous state. Enhancement goes a step beyond rehabilitation to provide additional benefits to wildlife, in this case cranes.

Controlling Vegetative Encroachment Within the Platte River Channel

Various techniques have been utilized to control vegetative growth within the Platte

River system. Of primary interest here are crane habitat management techniques which have been attempted by the National Audubon Society at the Lillian Annette Rowe Wildlife Refuge on the Platte River, between Nebraska State Highway 10 and Gibbon, Nebraska. (Logan, et al. 1975). According to Wicht (Pers. comm. 1979) and Frith (Pers. comm. 1979), the following general types of experimental programs have been conducted or proposed for control of vegetative encroachment:

1) Manual clearing
2) Mechanized clearing
3) Burning
4) Island obliteration (clearing and leveling)
5) Herbicide spraying
6) Flow maintenance

Manual clearing is very labor intensive and has only a short term effect since new shoots of willows, cottonwoods, dogwood, and indigo bush rapidly develop from the remaining stumps. Although local hunters regularly use this technique in constructing waterfowl hunting blinds on the river islands, the amount of labor required for such a short term benefit is very high, and thus not attractive for long term habitat management.

Mechanized clearing has been used by pulling various types of machinery over the vegetated islands. Disks, loaders, and rotary mowers ("bush hogs") have been used to knock down existing vegetation during minimum flow periods in late summer when this type of farm machinery can negotiate the river. Again, this type of clearing has only a short term effect due to rapid regrowth.

Burning has been practiced for some time on islands used for waterfowl hunting blinds to reduce understory vegetation on islands with willows growing to 8-10 feet tall. Although this is a very effective mechanism for removing understory vegetation, the willow growth seems to be enhanced since competing vegetation is removed and large willows are not destroyed by fire. Therefore, additional work is required to remove the willows.

Island obliteration has proven to be the most effective, and hence most promising, habitat management technique yet attempted. This procedure involves mechanical clearing of the vegetation and then leveling of the island to near base flow using a large caterpillar tractor. The technique removes most of the buried root stocks of the fast growing species, and promotes natural scouring (which represents very low cost maintenance) by returning the island to near base level. In the past, several waterfowl hunting blinds were constructed in the main channel near areas that had been cleared, levelled and diked to provide a more attractive waterfowl habitat. Until very recently no permits were required for this activity. Now, under Section 404 of the Clean Water Act, a permit is required by the U.S. Army Corps of Engineers, Omaha District, for this type of habitat management. To the author's knowledge, no permits have yet been denied.

Areas on the Lillian Annette Rowe Wildlife Refuge that had been subjected to island obliteration in 1977, had good sandhill crane utilization during the 1979 spring migration (Wicht, Pers. Comm. 1979). Also, vegetation remains in a very early successional phase as expected. The cost of this technique is high, on the order of $600/acre, but the longer term benefit promises to be more attractive than other methods.

Herbicide spraying is another alternative which has not received much attention, due to the relatively high risks associated with application to an aquatic system. However, in the late summer when little or no water occurs in the Platte River in this area, and most fish and other aquatic organisms have been caught, have moved on or died, potential exists for selective herbicide application to transitional islands with little risk to the aquatic environment. However, the problem of effective subsequent scouring has not been alleviated since no effort to reduce the height of the island would have been made.

Flow maintenance (to maintain scouring) has been the focus of attention for many years. However, due to the decrease in flow compared to historic values, the increasing demand for water upstream, and the acceleration of vegetative encroachment in recently utilized crane habitat, even the most optimistic outlook would be one of maintenance or slight decrease in open habitats. A massive flood could conceivably return much transitional crane habitat to the pristine condition, but the process of vegetative encroachment would immediately begin again. To achieve a positive approach toward rehabilitation and enhancement in light of decreasing flow, it appears that mechanical means should be considered as a viable habitat management tool.

Wet Meadow Habitat Management

The primary concern for wet meadow habitat management is centered on availability of groundwater. Without an adequate supply of water, wet meadows soon change toward a more xeric assemblage, and then become candidates for conversion to cultivation. Little research has been done on the relative use of wet meadows at different groundwater levels. Acquisition of wet meadows and diversion of water to them in the spring appears to be the only current technology for maintenance of wet meadows close to a "natural" state.

Just as the increasing height of vegetation on Platte River islands can discourage crane utilization (Frith 1974), sandhill cranes have shown an avoidance to wet meadows that grow too high (18-20") (Wicht, personal communication, 1979; Frith, personal communication, 1979). The National Audubon Society performed meadow burning in spring 1979 to remove higher vegetation from selected meadow habitats. The cranes did not utilize the areas (except at the fringes) before burning, but utilized these areas heavily within one week following burning. The only real drawback to this method is that there is a relatively rapid regrowth, and the method needs to be implemented frequently. However, mechanical removal by haying or grazing could probably also be used.

POTENTIAL ADVERSE EFFECTS

Any type of habitat management scheme has the potential for producing adverse effects, especially when habitat management is concentrated on one or two species. Any Platte River habitat management plan for maintenance of critical whooping crane habitat should give serious consideration to the other species that occur in the region, and depend upon the resource, including bald eagles, ducks, geese, various amphibians, reptiles, mammals, and other birds, especially breeding birds. The following potential adverse impacts are by no means inclusive, but indicate the different types of problems associated with the various habitat management schemes:

- Vegetation cleared from islands by manual or mechanical means could contribute to the trash and organic load of the Platte River.
- Burning causes air pollution.
- Many species of other important game and non-game wildlife utilize the existing habitat; including bald eagles, golden eagles, deer, cottontails, quail and herons.
- The fishery, although limited primarily to rough fish, could be affected by in channel activites which would alter water quality.
- Local waterfowl hunters utilize transitional islands for hunting blinds. Hunting opportunities may decrease due to open habitat maintenance in certain areas.
- Herbicide spraying could introduce toxic chemicals into the environment, and could affect desirable plant species.

There are, of course, a host of mitigation measures available to deal with these potential environmental impacts.

SUMMARY

Remote sensing studies utilizing 1938 and 1969 aerial photography indicate that there has been a substantial reduction (losses of 40 to 70%) in open river habitat potentially utilized by cranes due to channel narrowing and encroachment by woody vegetation within the "Big Bend" area of the Platte River system.

Vegetation succession in the Platte River islands consists of a low (1 to 3 foot) herbaceous dominated stage, followed by a low (4-6 feet) to tall (up to 15 feet) shrub stage dominated by sandbar willow, false indigo, and red dogwood. Eastern cottonwood saplings assume dominance and shade out intolerant sandbar willow and false indigo. Cottonwoods attain a height of 40 to 60 feet. Red dogwood persists as an understory shrub in cottonwood communities. Platte River island communities are too young (or too frequently disturbed) to have reached the regional climax floodplain forest community of green ash, American elm and boxelder.

The rate of successional change is directly related to the severity of flooding and scouring action by water and ice. The woody vegetation is highly adapted to tolerate mechanical injury from abrasion and burial in deposited sediment. The woody vegetation also shows a high potential for rapid growth when released from the scouring cycle. It appears from field observations that if an herbaceous island can remain free from major disturbance for a period of four to five years, it is unlikely to revert back to its original composition; if a tall shrub island is left undisturbed for a period of 10 to 15 years it is likely that it will succeed toward a tree-dominated island.

The river is extremely efficient in removing young woody seedlings from the channel, but the persistence of living woody root systems which send up shoots annually provides a source for a rapidly expanding shrub population.

The implications of these studies on maintenance, rehabilitation, and enhancement of open crane habitat are as follows:

1. When possible, efforts should be made to maintain the current river scouring cycle which is efficient in removing woody plant seedlings and new woody shoots.

2. Due to high potential growth rates in the absence of scouring, changes in vegetation structure can occur quite rapidly. This suggests that monitoring for vegetation change should be conducted at short intervals (1 to 2 years).

3. The great capacity of river shrub species to resprout after disturbance indicates great difficulty in eliminating these shrubs from existing islands. Complete removal of the root system is required for effective control.

4. Rehabilitation and enhancement efforts should probably be directed at islands with stems 8 to 10 years old, since these islands are at a successional stage where they will probably not be brought back to a lower successional stage by natural forces. Immediate action is required as many islands will pass through this transitional phase within the next two years.

5. The high level of use of the low to tall shrub islands by waterfowl hunters implies a potential use conflict between hunting and crane habitat maintenance.

6. Any habitat maintenance, rehabilitation, and/or enhancement should take into account the impact on other ecosystem components, especially other threatened, endangered, or otherwise important species.

7. Several habitat manipulation techniques exist for mitigation of flow depletion effects upon in-channel vegetative encroachment. Few techniques exist for maintenance of productive wet meadow complexes under reduced flows.

8. Intensive experimentation of selected habitat management techniques should be carried out, and success or failure should be determined by detailed monitoring. At this time, island obliteration followed by burning, disking, or mowing appears to be most promising.

9. Much additional research on whooping crane, sandhill crane, and other Platte River wildlife will need to be accomplished in order to formulate more specific habitat management plans.

10. A radiotagging program should be undertaken to identify whooping crane habitat use patterns within the Platte River valley and elsewhere. Continual reevaluation of the existing critical habitat designation should be made based upon new data and developing knowledge of whooping crane behavioral biology, and distribution.

Figure 10. Color intra-red aerial photograph of mature cottonwood stand in the Platte River channel upstream of the critical whooping crane habitat.

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Wildlife Benefits Through Construction and Management of Floodwater Retarding Structures[1]

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Abstract.--A survey of 60 floodwater retarding structures in central Texas revealed interest by landowners in fish and waterfowl management. A 1-year field study indicated that fish and waterfowl utilization varied in relation to physical characteristics. Results of the study changed agency policy on design and construction. Management is limited by lack of assistance to landowners.

INTRODUCTION

Under authorization of the Flood Control Act of 1944 (Public Law 78-534) and the Watershed Protection and Flood Prevention Act of 1954 (Public Law 83-566), small watershed projects have been developed in 48 states. As a part of these projects, over 13,200 floodwater retarding structures have been built by the Soil Conservation Service (SCS). These structures are commonly referred to as flood prevention dams, small watershed dams, or simply conservation dams. The primary purpose of the structures is flood control and they function by accumulating excessive runoff in upper areas of watersheds and releasing water slowly over a period of days. Lakes created by these structures are designed to hold sediment and prevent its downstream movement; water storage capacity is reduced as sediment accumulates. Some structures are built on permeable soils or cavernous areas and do not contain permanent water. Relatively little is is known concerning the value of these lakes for fish and waterfowl (Lea and Mattson 1974; Nord 1963) and documented evidence on the effectiveness of wildlife management practices is lacking. This paper will describe wildlife resources (including fish) of these lakes, present some effects on resource management obtained through research, and provide a basis for increased attainment of their wildlife potentials.

FLOODWATER RETARDING STRUCTURES AND THE SMALL WATERSHED PROGRAM

Floodwater retarding structures are an integral part of small watershed projects where dams are built and other measures used to reduce or control flooding, erosion, and sedimentation. Multipurpose projects may also provide water storage for municipal, industrial, recreational, or irrigation use. Sometimes multipurpose lakes include facilities which increase recreational opportunities and improve fish and wildlife resources. Land treatment practices to reduce erosion and sedimentation are also integral parts of all small watershed projects.

The small watershed program, administered by the SCS, is a program of federal assistance rather than complete federal ownership and control; consequently, decision making largely remains in the hands of local people. Small watershed projects are based on local initiative and responsibility. Local entities of government make application for assistance, and priorities are established by the state governor.

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Local project sponsor groups are responsible for acquiring land, easements, and needed rights-of-way for all structures. They share the cost of multipurpose structures and are responsible for operating and maintaining all the project measures when construction is completed. SCS provides technical help in planning and installing structures.

CHARACTERISTICS OF FLOOD PREVENTION LAKES IN CENTRAL TEXAS

Texas has over 1,750 floodwater retarding structures. Of these, 260 are in the Richland, Chambers, and Grays Creek portion of the Trinity River watershed.

Flood prevention lakes are typically larger than farm ponds, with surface areas of 6 to 16 hectares (15 to 40 A). In contrast, farm ponds are generally less than 0.4 hectare (1 A) in size. The ratio of drainage area to (permanent water) storage is usually much greater in flood prevention lakes than in farm ponds. Therefore, flood prevention lakes have much higher water exchange rates. Also, fluctuations in depth, surface area, and volume are more frequent and severe than in farm ponds. Many farm ponds do not have a drain pipe or other means of water level control. In contrast, flood prevention lakes are designed with a principal spillway generally consisting of a concrete vertical inlet and conduit through the base of the dam (fig. 1). Water flows through this spillway when water levels exceed the elevation of the inlet (sediment pool volume). It is generally impossible for fish from downstream to enter the lakes through these spillways. Conversely, fish commonly enter farm ponds from downstream when water flows through excavated spillways. Flood prevention lakes have emergency spillways that seldom function because structures are designed with detention pool capacities sufficient to hold water from most floods.

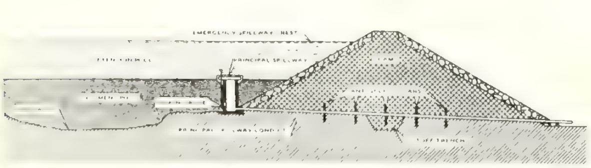

Figure 1.--Section of a typical floodwater retarding structure. Courtesy of Soil Conservation Service.

PL 83-566 flood prevention lakes also differ from reservoirs constructed on major streams. Reservoirs are generally much larger and deeper and have greater shoreline development. They often contain standing timber and are generally built on perennial streams. Flood prevention lakes have greater flexibility than reservoirs when water level control is desired for fish or waterfowl management. Factors other than benefits to wildlife usually govern water level manipulation on large reservoirs.

Flood prevention lakes combine the attributes of both farm ponds and large reservoirs for wildlife management. Like farm ponds, most flood prevention lakes are built on private land and access for hunting and fishing can be controlled. Water level manipulation permits vegetative plantings, aquatic weed control, controlled spawning of fish, exposure of excessive prey fish to predator fish, and stabilization of basin and shoreline.

In most instances, conditions favorable to wildlife associated with these lakes have resulted incidentally rather than through planned design. Management recommendations have been of a general nature due to an absence of specific data concerning applicable techniques. Increased emphasis is being given to wildlife resources in the planning of structures in new watersheds.

STUDIES OF FLOODWATER RETARDING STRUCTURES IN CENTRAL TEXAS

In 1975, a cooperative agreement between the SCS, Texas Agricultural Experiment Station, and Texas Agricultural Extension Service (TAEX) was initiated to determine fish production and waterfowl use of floodwater retarding structure Each of these agencies, with additional support from the Caesar Kleberg Research Program in Wildlife Ecology, contributed to the funding of the project. Emphasis was placed on finding the characteristics of flood prevention lakes that favor sport fish and waterfowl, with the goal of identifying appropriate management practices, both pre- and post-construction, tha would enhance these resources.

Initially, 60 structures were included in the program. A questionnaire was filled out at each site by SCS field personnel who interviewe each landowner. Permission for field surveys o fish populations and waterfowl use was also acquired during this interview. The survey ind cated that the most popular recreational uses o the lakes were fishing and hunting (Pate 1979).

Ninety-five percent of the lakes were fished, and people hunted on 45 percent. Most hunting and fishing activities were done by families and immediate friends; however, some lakes were leased for recreational purposes. Landowners estimated their average annual fish harvest to be nearly 100 kg, slightly over 11 kg per hectare. Average waterfowl harvest from those lakes which were hunted was estimated to be only 14 ducks per year. Over half the landowners had attempted to improve their fish population, principally through stocking. In four of the study lakes, owners had attempted food and cover plantings for waterfowl management.

Approximately half the lakes were owned by one individual. The remaining lakes extended onto property of more than one landowner. The number of owners was inconsequential as a factor affecting recreational uses and management.

A 1-year field study of fish population characteristics and waterfowl use was conducted in 1976-77. Fish catch statistics and waterfowl count data were analyzed in relation to physical, limnological, and biological characteristics of the lakes. In 56 lakes sampled for fish by seining, electrofishing, and gillnetting, 23 species were found. Dominant species were largemouth bass, bluegill, redear sunfish, green sunfish, black bullheads, channel catfish, white crappies, and golden shiners (Farquhar 1977). Except for golden shiners, these species closely paralleled the target sport fish listed by landowners in the questionnaire. These lakes varied markedly in size, age, average depth, and water clarity. Generally shoreline development was low, and cover in the form of standing or fallen timber was negligible.

Analyses revealed that channel catfish and sunfish populations were more closely correlated to physical and limnological characteristics than were those of other species. Channel catfish populations were highest in large, turbid lakes with little shoreline development and deep thermal stratification. In contrast, sunfish were favored in clear lakes with high ratios of drainage area to surface area, deep stratification, and long shorelines. Largemouth bass, black bullhead, and white crappie populations were poorly correlated with physical and limnological variables. Largemouth bass populations were more closely related to prey species characteristics than to physical or limnological characteristics.

Incidental observations indicated that the lakes generally had an acceptable balance between predator and prey species. Frequent overpopulation of white crappie and occasional overpopulation of sunfish were noted. Only one lake had a severe overpopulation of largemouth bass. Concentrations of fish around occasional sunken logs and inundated brush indicated a shortage of cover for some species. Excessive aquatic vegetation that interfered with fishing from shore was common, but apparently had no adverse effects on fish populations.

Waterfowl surveys were conducted on 55 lakes from August 1976 through April 1977 (Hobaugh 1977). Bi-weekly aerial surveys, accompanied by ground counts, indicated that a total of 18 species of waterfowl utilized these flood prevention lakes. The 55 lakes typically held about 2,300 ducks and 360 coots. Geese comprised only 2.5 percent of the waterfowl observed. Six species of large wading birds, predominantly cattle egrets and great blue herons, were observed.

Puddle ducks comprised 77 percent of the ducks observed, principally gadwall, American wigeon, green- and blue-winged teal, and mallard. Ring-necked ducks were the most numerous diving duck. Numbers of ducks observed closely followed the migration patterns of duck species through the area. Maximum numbers occurred in late November and late March when over 4,000 ducks were counted. Midwinter minimum counts remained high, with about 2,000 ducks observed on each count. Observations of waterfowl on farm ponds and the four large reservoirs in the area rarely indicated comparable concentrations.

Analyses showed that the main characteristics associated with the use of flood prevention lakes by waterfowl were the amount of aquatic vegetation and surface area of lakes. Lakes with clear water typically supported large stands of submergent vegetation and attracted large numbers of waterfowl. However, ducks were observed on all lakes at sometime during the study. Emergent vegetation was generally lacking because of livestock grazing and water level fluctuations.

Several other noteworthy observations relating to waterfowl were made during the study. Waterfowl use was independent of proximity of lakes to roads and homesteads. Maximum use occurred on the only lake with islands. These islands were used extensively as loafing areas. Waterfowl use appeared to decline on some lakes as aquatic vegetation was depleted. Plantings of winter wheat and oats in fields adjacent to the lakeshore attracted large numbers of geese and wigeon.

IMPLICATIONS FOR DESIGN AND CONSTRUCTION

Data obtained from these studies have been partially responsible for modification of SCS policy in Texas. These modifications have been implemented with regard to improvement of lakes for both fish and wildlife.

Present policy permits borrow areas to be confined to minimize the loss of terrestrial habitat. Confining borrow areas may increase cost, but results in a smaller lake with a greater average depth. Deeper lakes may prevent loss of fish populations during dry periods and provide a more dependable water source. Lakes with smaller surface areas are less subject to shoreline erosion caused by wave action. Reduction of surface area of lakes may also be accomplished by porting the principal spillway at lower elevations. Conversely, when waterfowl habitat is an objective, features which increase surface area and improve water quality may be incorporated.

SCS policy on removing trees from flood prevention lakes has been modified to retain trees that provide cover for fish or habitat for other species. Leaving timber in flood prevention lakes also reduces wave action, results in less soil disturbance during construction, and may reduce the cost of construction. The amount of timber retained and its location must not affect the primary function of the structure.

Biologists have long recommended fencing sediment pools to exclude livestock when improved shoreline habitat and reduced turbidity were desired. This study confirmed the need for fencing to exclude domestic livestock grazing when waterfowl food plantings are made. Fencing of sediment pools as a part of the construction cost is permissible whenever needed to offset or compensate for the loss of terrestrial habitat resulting from construction of the dam.

IMPLICATIONS FOR MANAGEMENT

Besides impacting design and construction features, the study also provided recommendations for management which could be undertaken by the landowner. Fish and wildlife measures added by landowners which do not interfere with the planned function of the structure or affect its safety are generally allowed. Immediate seeding of all disturbed areas with annual grasses should provide both additional direct and indirect control of turbidity. Immediate closing of the drain valve upon structure completion will minimize contamination by undesirable fish species from downstream. Additional cover can be provided by minor alterations of shoreline and construction of earthen piers, both of which simultaneously increase accessibility from shore. Likewise, islands for duck loafing areas can be built, and waterfowl plantings established.

With some refinement, conventional fishery management techniques can be applied to floodwater retarding structures. Initial stocking and water level manipulation appear to have the greatest potential for success, both from the standpoint of anticipated results and land interest. Most landowners in the study area now seek professional recommendations for stocking their lakes. Owners of 12 lakes participated in a lake drawdown during the summer of 1977 to improve fish populations. Food plots were also established to increase waterfowl use.

A lack of assistance has limited successful fish and wildlife management by landowners. The SCS and TAEX have a very limited number of biologists available to help private pond owners. Due to personnel constraints, state fish and wildlife biologists are unavailable to provide extensive field assistance. Field personnel of the SCS and TAEX are trained in farm pond management, but few are adequately trained or equipped to deal with the more complex management needs of larger lakes. This study provides a factual basis for making specific recommendations on floodwater retarding structures. Making these recommendations available to various field personnel, biologists, and landowners themselves should help overcome this limitation and stimulate more effective management.

BENEFITS

Floodwater retarding structures in central Texas have typically been built on valleys and intermittent waterways through cropland and pastureland. Although loss of productive land occurs, most landowners have looked favorably on the structures as providing a number of benefits to them. Because the lakes remain in the private sector, opportunities for recreation are substantial enough to attract interest in proper management by landowners. As a result of this study, increased benefits can be realized to those who wish to follow through with management.

Results of this study also apply to other artificial impoundments. Management techniques such as drawdown and corrective stocking of game fish have direct implications for farm ponds and large reservoirs.

This project also represents a unique integration of expertise brought to bear on a resource of mutual interest. In addition to biologists from cooperating agencies, the project closely involved SCS field personnel and landowners. Other people involved through field day activities included county extension agents, state and federal fish and wildlife personnel, and water resources personnel. These individuals were familiarized not only with landowner interest in fish and wildlife, but also the potential for improving these resources through management.

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Environmental Considerations in Engineering Designs: Little Black Watershed[1]

John J. Walker[2]

Abstract.--The Little Black Watershed PL-566 project in Southern Missouri is a demonstration of combining flood prevention measures and environmental features to develop an environmentally sound watershed plan. The three major areas of environmental concern were: (1) maintaining the Little Black River in its natural condition, (2) preserving the remaining hardwoods and (3) maintaining or improving the fish habitat in manmade ditches.

INTRODUCTION

The Watershed Protection and Flood Prevention Act (Public Law 83-566) was enacted in 1954. It established a popular program for solving water and related land resource problems. Since then many rural and urban communities have shown that they can halt unchecked erosion and excessive water runoff. Approximately 1,200 projects nationwide have been approved for construction.

In 1969 the National Environmental Policy Act placed additional emphasis on analyzing the social, economic, and ecological effects that water resource projects have on man's environment. About this same time, the Soil Conservation Service strengthened its environmental policy to encourage measures to enhance the environment and to lessen the adverse impacts of structural works of improvement.

The Little Black Watershed Plan in southern Missouri and northern Arkansas is an example of how the Waterhsed Protection and Flood Prevention Act can help in developing a comprehensive resource plan for protecting a watershed and its environment. This watershed plan was developed by local, state, and federal interests who acted jointly to define the problems and then identify acceptable solutions.

The Little Black Watershed is located in Butler, Carter, and Ripley Counties in southeastern Missouri and Clay County in northeastern Arkansas. Little Black River is a left-bank tributary to the Current River (fig. 1).

The Little Black River is located in the Current River subbasin of the Arkansas-White-Red Water Resource Region. The region consists of two Major Land Resource Areas (MLRA's). The largest MLRA is Ozark Highland, which consists of rolling hills that are 80 percent forest, 5 percent cropland, and 15 percent pasture. The other major area in the region is Land Resource Area 131, Southern Mississippi Valley Alluvium, which is located in the lower part of the basin known locally as the delta area. The land use in this area is 77 percent cropland, 16 percent pasture, and 7 percent forest.

Except for a narrow band at the State line that ranges from 100 feet to 1 mile wide and parallels the river, all the area northwest of the Little Black River is located in the Ozark Plateaus Physiographic Province. This region consists primarily of rolling hills and 75 percent of it is covered by forest. Local relief in the upland ranges from 40 to 120 feet. In some areas adjacent to the Little Black River, the relief ranges up to 180 feet. Flood plains along streams in the upland are 300 to 2,000 feet wide.

The land southeast of the Little Black River is in the Southeastern Lowlands Physiographic Province, and is locally referred to as the delta. The delta consists of a broad arm of the Gulf Coastal Plain that extends up the valley of the Mississippi River from the Gulf

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

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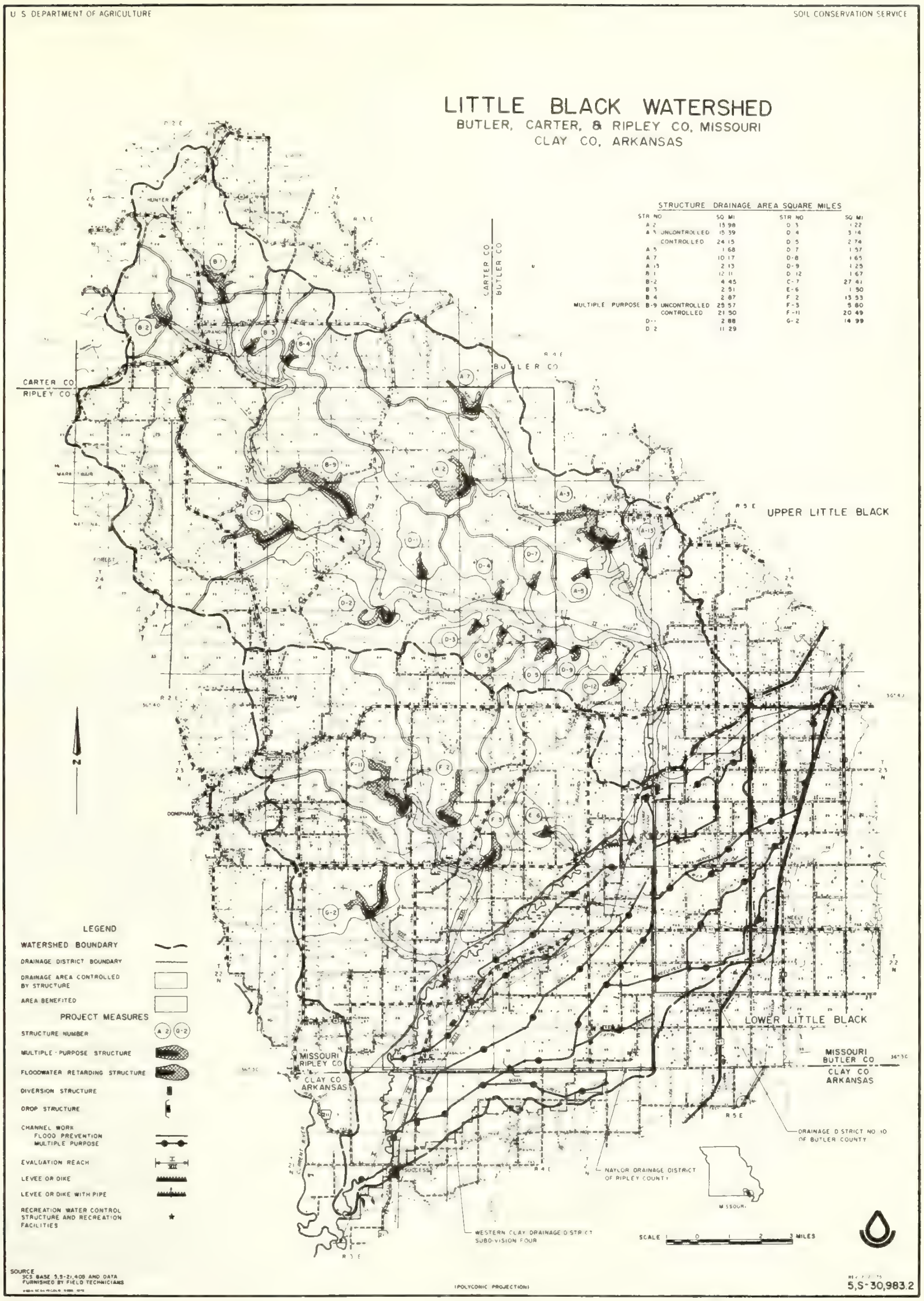


Figure 1.--The project map for Little Black Watershed identifies the watershed boundary, physical features and structural measures to be installed.

of Mexico to southeastern Missouri. The delta ranges from level to depressional with scattered, gently undulating sandy ridges and hummocks. All the Arkansas portion of the watershed, except a few acres near the State line, is in the delta.

The drainage pattern is dendritic with major streams flowing to the southeast. The Little Black River begins in Carter County near Hunter, Missouri, and flows southeast. Beaverdam Creek, the major tributary, joins Little Black approximately 2 miles north of Highway 160. From Highway 160 the river turns southwest, across the delta, and joins the Current River in Clay County, Arkansas. Other tributaries to Little Black River include South Prong Little Black River, North Prong Little Black River, and Flat Creek. They are unmodified, well-defined natural streams that have intermittent flow.

As it leaves the uplands, the Little Black River follows the trend of the Ozark Escarpment. It enters the lower watershed approximately 2 miles northeast of Naylor, Missouri, and follows a meandering southwest course to its confluence with the Current River near Success, Arkansas. Principal tributaries in this area are Harris, Logan, Cypress, and Caldwell Creeks and Buzzard Run. These are well-defined natural streams that have perennial flow in their lower reaches.

The source of the Little Black River is in the Upper Ozark Highlands in the upper Little Black Watershed where it is a high gradient spring-fed stream. Streams that drain areas of less than 15 square miles are generally intermittent. As drainage is accumulated or lower elevations are reached, the Little Black becomes a perennial stream. The channel throughout the upland region has a gravel bottom, clear water, and a pool and riffle pattern. As it leaves the upland, the stream changes character. A transition section begins about 1 mile above U.S. Highway 160 and extends to the delta area. The water becomes more turbid, deeper, and generally more sluggish there. The channel bed changes from gravel to fine sand, then to silt and clay, and it begins to meander. The meandering continues for 26 miles to the lower Little Black Watershed's outlet at the Current River.

The delta is served by a system of manmade ditches that were built by drainage districts between 1910 and 1930. Most of these ditches are parallel to the Little Black River and serve as outlets for runoff from the delta.

As it leaves the Ozark Escarpment, the Little Black River has a bankfull capacity of 1800 cfs and a slope of 1.7 feet per mile. As the river moves through the delta, its bankfull capacity decreases to 600 cfs and its slope to 0.2 foot per mile. This condition causes a serious flooding problem in the delta and was the primary reason the local residents requested assistance under Public Law 566. Floods occur three or four times a year and cause an average of $1 million in damage to crops.

In 1964 the Governor of Missouri requested planning assistance from USDA under the Watershed Protection and Flood Prevention Act on behalf of the sponsors. The sponsors included three drainage districts, four soil and water conservation districts, and four county governments.

This paper focuses primarily on the provisions that were considered to improve the environment and how they merged with the measures for flood prevention.

PROJECT FORMULATION

Three major environmental concerns were identified during planning:

1. Maintaining the natural channel on the lower Little Black River and the ecosystem associated with it.
2. Preserving the hardwood forest habitat in the delta and its diverse wildlife.
3. Maintaining or improving the fishery habitat in manmade ditches in the delta and along the Little Black River.

Maintaining the Little Black Channel

As it leaves the upland through the foothills, the Little Black River is a stable incised channel with a capacity of approximately 1,800 cfs. The rapidly decreasing grade as the river enters the delta reduces this capacity by over 50 percent and causes a frequent flooding in the delta area.

The flooding has created a natural levee along the main channel. The velocity in the main channel enables floodwaters to carry a large sediment load. When the floodwater is spilled out onto the broad delta, its velocity decreases and most of the sediment is dropped. Over many years the delta has developed a natural barrier that prevents floodwaters from returning to the natural channel.

The frequent flooding has also cut scour channels through the natural levees to the manmade channels. Over a period of time, these have eroded to the point that they are serving as a principal floodway. Because deposition of sediment continues in the lower Little Black River and the scour channels continue to erode the levees, eventually the Little Black River would be diverted down the manmade channels. This development would replace 30 miles of a meandering natural stream with 15 miles of channel through prime agricultural lands.

The watershed plan includes several measures to reduce the deterioration of the natural river channel through the delta. These measures and their effects are:

1. The construction of 25 structures to retard floodwater which will reduce peak flows and the delivery of sediment.
2. The construction of four levees across scour channels to prevent the river from being diverted down the drainage ditches.
3. The construction of a bypass floodway with a water-control structure to maintain bankfull flows in the river and divert excess flows down the floodway.

The water-control structure (fig. 2) will consist of a dam across the Little Black River with four 48-inch reinforced concrete conduits. The bottom of the diversion channel will be 4.5 feet above the river channel bottom and will be riprapped to protect it from erosion. This will contain all flows of less than 375 cfs but will limit the maximum flow to 1,000 cfs in the natural channel as indicated in figure 3. Most of the excess flood flow for a 2-year frequency storm will be diverted into the floodway. Storms greater than 2-year frequency will continue to cause some flooding. Openings will be maintained in the spoil banks every ¼ mile to allow excess flows to occur normally.

Preserving Hardwood Forest Habitat

Prior to settlement in the 1830's, the delta was primarily a swamp forest with scattered sand ridges. The cypress, oak, ash, and sweetgum trees were a valuable lumber resource and were harvested from 1875 to 1900. Many channels were constructed to move the logs to the sawmill. These channels were later used

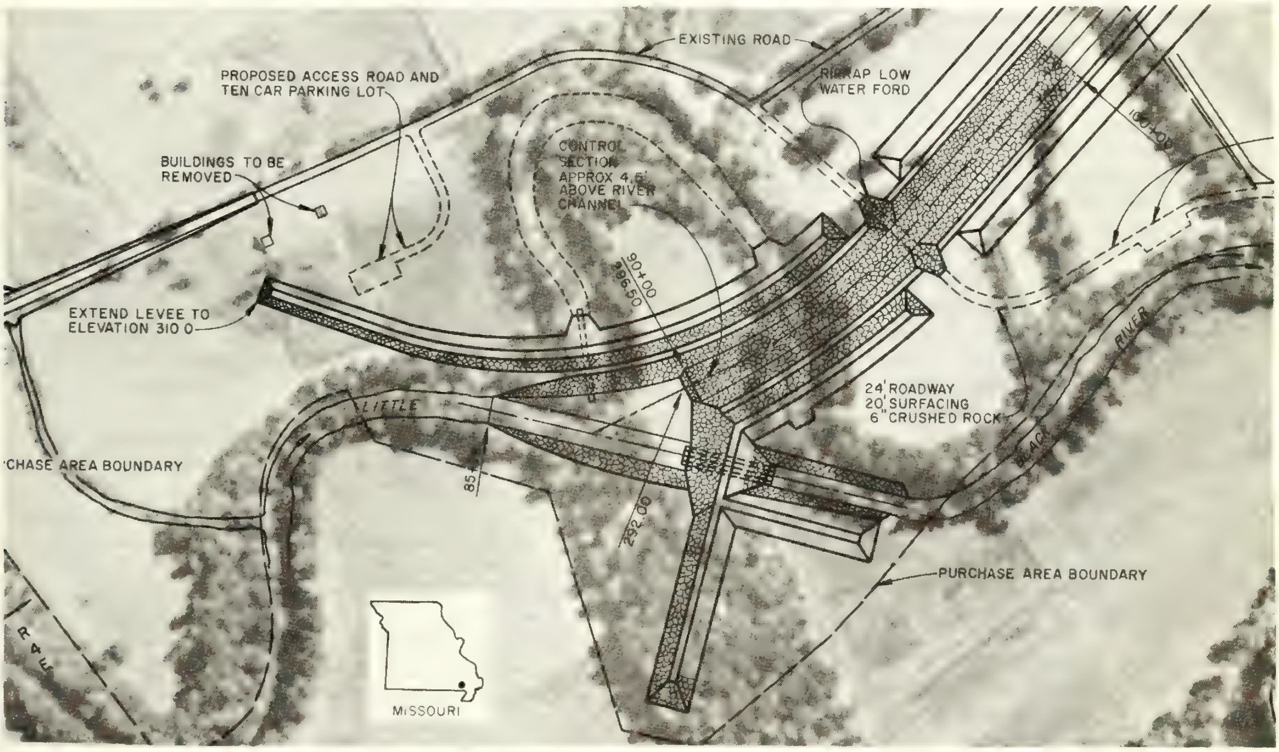
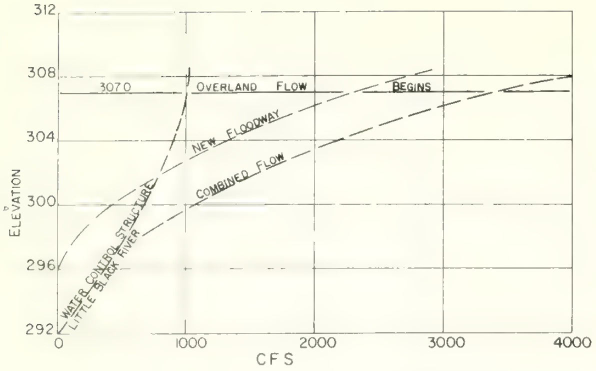


Figure 2.--This diversion structure will regulate the flows between the Little Black and the bypass floodway. Four 48-inch pipes through the fill across the Little Black River maintain the natural channel flows. The rock riprap control section at the floodway's entrance will prevent degrading of channel to intercept low flows. The crest of the floodway entrance is 4.5 feet above the bottom of the Little Black channel.



LOWER LITTLE BLACK WATERSHED
FLOW AT DIVERSION STRUCTURE
FIGURE 3

Figure 3.--The graph identifies the flow characteristics of the diversion structure by elevation. Elevation 292 is the river bottom and elevation 307 is natural bank.

for drainage when the lands were converted to agricultural production. This clearing of timber continued and now less than 7 percent of the delta is forested. The present forested land in the delta, except for narrow strips along the drainage ditches and Little Black River, consists of scattered tracts ranging in size from 2 to 320 acres. The narrow strips along channels provide most of the remaining valuable forest cover for fauna associated with the swamp forest and serve as valuable travel lanes for other wildlife. These travel lanes provide protection for birds and small mammals moving between isolated tracts of cover. The lanes also provide access to food (crop fields) and water.

An analysis of all the manmade ditches in the delta revealed that they do not have the capacity to handle flood flows. The traditional method of enlarging a ditch is to clear both its sides, but this would destroy much of the remaining forest habitat. Individual landowners are clearing the timber along the drainage ditches to keep the trees from competing with their crops. Most of the timber corridors along the channels are projected to be cleared in a few years.

After considering several alternatives for preserving forest habitat, the sponsors chose the following measures:

1. Construction in small ditches will take place on only one side of the channel as shown in figure 4. This will leave the habitat on the other side undisturbed.
2. The Naylor Drainage District in Ripley County, Missouri, and the Clay County Drainage District in Arkansas will obtain restrictive easements to prevent landowners from clearing the undisturbed habitat.
3. The Butler County Drainage District will obtain 100 acres of delta land to be managed for wildlife. This includes 50 acres around the diversion structure.
4. The floodway and Ditch No. 3 (main ditch) will be constructed from both sides as shown in figure 5. The spoil banks will be leveled at 10 feet above natural ground level. The spoil banks on both sides of the main ditch will have 3:1 inside slopes and will be 30-feet wide. They will be planted to grasses and woody vegetation for wildlife.
5. Fences will be constructed along the crown of the spoil banks to protect the wildlife plantings from livestock grazing.
6. To maintain water and habitat in three oxbows that will be cut off by changing the direction of the Little Black River, a pipe will be placed in fill across the channel.

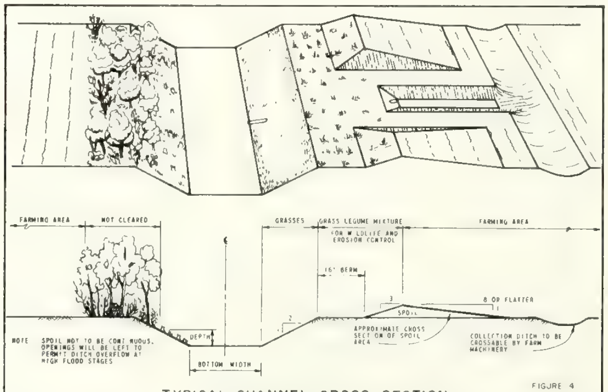

FARMING AREA
NOT CLEARED
GRASSES
GRASS LEGUME MIXTURE FOR WILDLIFE AND EROSION CONTROL
FARMING AREA
16' BERM
3
8 OR FLATTER
1
2
1
SPOIL
DEPTH
BOTTOM WIDTH
APPROXIMATE CROSS SECTION OF SPOIL AREA
COLLECTION DITCH TO BE CROSSABLE BY FARM MACHINERY
NOTE SPOIL NOT TO BE CONTINUOUS. OPENINGS WILL BE LEFT TO PERMIT DITCH OVERFLOW AT HIGH FLOOD STAGES

FIGURE 4

TYPICAL CHANNEL CROSS SECTION
SHOWING CONSTRUCTION WORK FROM ONE SIDE TO SAVE EXISTING WILDLIFE HABITAT ON OPPOSITE SIDE

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Figure 4.--The typical channel cross section shows plans for constructing small channels from one side. An easement is being acquired from the landowners to preserve the undisturbed habitat.

Maintaining or Improving the Fishery Habitat

The fish of the upper Little Black River are extremely varied because of the diversity of aquatic habitats. A total of 75 species has

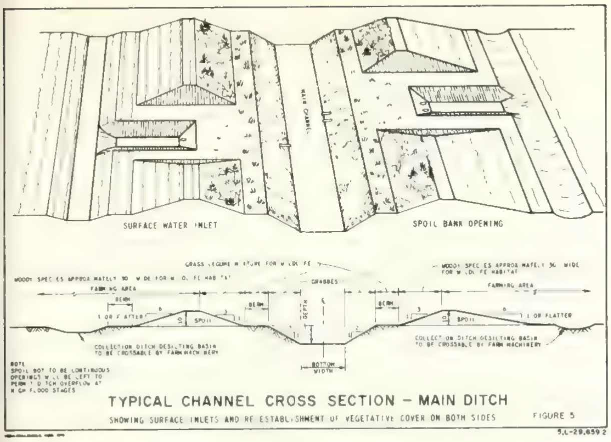
SURFACE WATER INLET
SPOIL BANK OPENING
MAIN CHANNEL
TYPICAL CHANNEL CROSS SECTION - MAIN DITCH
SHOWING SURFACE INLETS AND RE-ESTABLISHMENT OF VEGETATIVE COVER ON BOTH SIDES
FIGURE 5

Figure 5.--The typical cross section shows a plan for reestablishing a 30-foot-wide wildlife planting on each side of the channel. This planting plan is applicable to the floodway channel and Ditch No. 3 from the diversion structure to Success, Arkansas.

been collected from the watershed. The fishery is typical of a good Ozark stream and has excellent water quality conditions.

Ports were included in all dams on perennial streams to maintain low flows and fisheries. Data were insufficient in the planning stage to determine if water releases should be incorporated into the principal spillways on the dams to control water temperature for the warm water fishery. A study will be made during the construction stage to determine if they should be added.

Within the pools created by the floodwater retarding structures, cleared vegetation will be used to build root wad piles for fishery habitat. The 25 dams create 1,368 acres of new flat water fishery.

The fishery in the mandmade ditches is of much lower quality but is still considered significant. The area is well supplied with ground water and, even after a 6-week drought, water in some parts of the ditches is 3 to 6 feet deep and maintains rather large fish populations. The typical fish in these ditches include largemouth bass, bluegill, bowfin, and European carp. The old, heavily vegetated ditches support approximately 48 pounds of catchable sportfish per acre and 453 pounds of catchable rough fish per acre. Some of the ditches are very popular fishing locations.

The following measures are incorporated into the watershed plan to support fisheries in manmade ditches in the delta area:

1. Four wet-weir concrete drop structures are included in Ditch No. 3 (main ditch) which is being used to divert flood flows from the Little Black River. Figure 6 is a sketch of one of these structures. Water will be approximately 4 feet deep upstream from the structure. Each structure will back water to the next structure upstream. The wet-weir structures are expected to reduce maintenance problems. They will reduce meandering caused by low flows in the 100-foot-wide floodway. The ponded areas should also reduce willow growth. The four wet-weir structures will impound 175 acres of water for fishery habitat. Each weir will have a 1 square foot port opening near the bottom. This will permit water to flow and fish to pass from one pool to another.

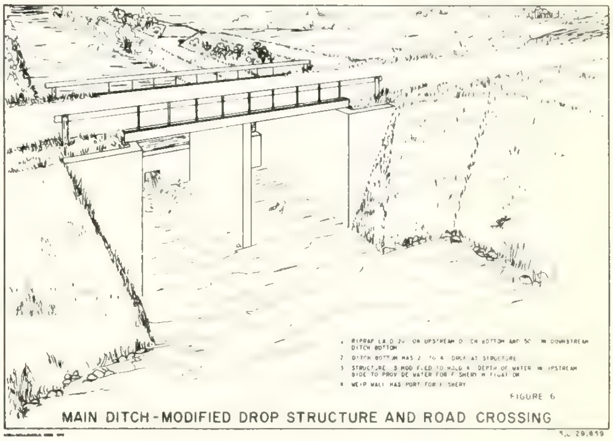

Figure 6.--Four drop structures are included in Ditch No. 3 (main ditch) and create pools in most of the channel area. Three of the structures will also serve as bridge abutments for road crossings.

2. Ditches No. 1 and 2 will be constructed so that an extra 2 feet of excavation will deepen alternate 1,000-foot sections of the ditch. This excavation will create a series of pool impoundments for fisheries.

3. Conduits will be installed in levees across two of the scour channels to maintain low flows. These channels have developed to such a depth that some of the base flow of the river continues to flow through these ditches. One of these channels will maintain a flowing stream through the pools created in Ditch No. 2.

4. To control erosion, all inflows to manmade channels will be through inlet structures. A 50-foot drainage collection basin will be excavated at least 2 feet below the crest of each inlet structure. These basins will trap much of the sediment and nutrients associated with the sediment. This will improve the water quality in the manmade ditches.

5. The three oxbows of the Little Black River that are to be cut off by construction will be blocked at both ends and pipe culverts will be installed to maintain existing water levels for fishery habitat. One oxbow will be cut off by construction of the diversion structure. The other two oxbows involve realignment of the Little Black River channel near Success, Arkansas. The drainage districts have agreed to acquire the land involved with each oxbow and enter into an agreement with the State Fish and Wildlife agency for management as a wildlife area.

Several other environmental considerations were incorporated into the plan:

1. The planners moved the proposed entrance to the floodway to preserve some large beech trees.

2. The plan for recreation development was modified to eliminate adverse impacts on a major archeological site. Another archeological site found at the diversion structure will be covered with borrow material to preserve it, and will be used for parking in the stream access area. Some of the channel work was relocated to prevent damage to other sites.

3. The last major tract of mature shortleaf pines in the watershed was included in the land acquisition for the state park near the multipurpose structure.

PUBLIC INVOLVEMENT

The measures in the Little Black Watershed plans were accomplished by stressing a positive approach. An inventory of the wildlife resources was presented with an explanation of the importance of the habitat to maintain the resource. Several alternatives were discussed to meet the goals and minimize adverse impacts. Three major areas need to be stressed in planning mitigation measures:

1. In preparing a plan, the sponsors need to recognize the importance of all the resources in the project area.

2. The professional should provide inventory data, effects of various proposals, and recommendations for minimizing or mitigating adverse impacts.

3. The measures in the plan should be determined jointly with sponsors and natural resource professionals. Through counter proposals, tradeoffs, and compromise, projects can result that are environmentally sound.

The Little Black Watershed Project proves that features to protect the environment can be incorporated into a flood control project. These measures are expected to add very little to the cost. They were developed with the participation of sponsors who accepted them readily. They expanded the objective of the project to include protecting the ecological system along with meeting the sponsors' primary goal of flood prevention.

Proliferation of River Deltas in Reservoirs: A "Natural" Mitigative Process?[1]

Jack A. Stanford[2]

Abstract.--Sedimentary and ecological dynamics of riverine-formed deltas in Lake Texoma, Texas and Oklahoma, and Flathead Lake, Montana, illustrate importance of alluvial wet lands to river-reservoir ecosystems. Natural creation of deltas may be considered mitigation of habitat lost by reservoir construction. Conversely, destruction of existing delta habitat by mismanagement of lake level regima may present mitigation problems.

INTRODUCTION

Dams now impound segments of nearly every major river in the United States, due to incessant demand for flood control, hydropower generation, and industrial, municipal, and agricultural water supplies. Many of these rivers carry large volumes of sediment into upstream reservoirs; the process may be largely natural and related to spates in drier or easily erodable areas and/or a result of poor land management within the drainage basin.

Fluvial sediments are deposited primarily at the upstream end of the reservoir, especially during floods. The result is natural formation of sediment fans or deltas at the river mouth. After a period of years much of the delta may be above water, allowing colonization by plants which help hold existing alluvia and additional sediments during floods. The size and rate of formation of river deltas in mainstream reservoirs are related to fluvial and flow processes and bed load in the river as well as reservoir age, morphometry and extent of volume regulation. The mechanics of delta formation at river mouths have been reviewed by Wright (1977), but are based mostly on deposition in marine environments.

Construction of mainstream reservoirs is often criticized (perhaps rightly so in many cases) for destruction of important riverine-riparian habitat for wildlife and low cost-benefit ratios imparted by projections of short-term (e.g. 30-50 years in the Southwest) filling of the lake basin by fluvial sediments. I propose that formation of river deltas in reservoirs should be viewed as a beneficial process that creates valuable wildlife habitat. The formation of a depositional delta and concomitant succession of flora and fauna may be viewed as a sort of natural mitigation of habitat destroyed or at least grossly altered by river impoundment. However, maintenance of water levels in the reservoir near full pool for extended periods may cause subaquous deposition of sediments due to continuous downslope movement of sediments by wave action; existing deltas in volume-regulated lakes and reservoirs may be eroded by wave action, thus destroying most of the positive attributes of delta formation. I propose that such erosion of existing deltas is a negative environmental impact worthy of mitigation. These ideas are supported by the following case histories.

LAKE TEXOMA, TEXAS AND OKLAHOMA

The Red River delta in Lake Texoma (see fig. 3 in Silvey and Stanford, 1977) is a good example of extreme alluvial deposition, characteristically occurring in southwestern river-reservoir systems. The reservoir was built in the early 1940's primarily as a flood control and hydroelectric project. Waters in the reservoir have never been maintained near flood storage levels and, therefore, large expanses of land within boundaries of the reservoir remain above water most of the time. Sediment deposition during floods has created 75-100 km^2 expanse of delta wetlands. New levies are established periodically by the river as it carves new channels in its attempt to move sediments further into the reservoir basin. Riparian and aquatic vegetation has responded in various successional stages: salt cedar (*Tamarix pentandra*), willows (*Salix* spp), cottonwood trees (*Populus* sp.), and various weeds and grasses have become established in the more or less stabilized sediments that are influenced by the more extreme flood stages. Buckwheat (*Polygonium* sp.), cattail (*Typha* sp.) and various sedges are very productive between floods on the lower areas of the delta. Production of planktonic and periphytic algae and other microbiota appears to be profound in the shallow waters. Fishes in these shallows are diverse and profusely abundant. A surprising diversity of waterfowl and aquatic vertebrates prey upon them. Coyotes, white-tailed deer, feral hogs, bobwhite quail, beaver and other wildlife may be seen on the higher, densely-vegetated portions of the delta.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 17, 1979.

[2] Director, Flathead Research Group, University of Montana Biological Station, Bigfork, Montana 59911.

The Red River delta in Lake Texoma is prime wildlife habitat that has naturally eventuated in a truly altered ecological situation. Some colonizing and apparently proliferating species are not completely indigenous to the area. This is particularly true for the bird populations. White pelicans (*Pelecanus erythrohynchos)*, for example, were never observed along the Red River in North Texas prior to construction of Lake Texoma. Hundreds of these birds may now be observed overwintering on the delta. They apparently find an abundant food supply in the shad (*Dorosoma cepidianum*) populations that reproduce profusely in the shallow waters of the delta. Many other shore birds, ducks and geese utilize the delta in similar fashion. Very large flocks of these central flyway migrants appear to spend lengthy stopovers on the delta. The microbiota of the delta is equally fascinating ecologically. Primary productivity proceeds at a high rate in response to nutrients contributed by the river as well as from excrement by waterfowl. I have measured diurnal fluxes of dissolved oxygen in excess of 14 ppm. and carbon fixation rates range between .3-.8 mg c l^{-1} hr^{-1}. Primary production by phytoplankton appears to be more important in the shallows than by rooted aquatic plants because of the continuous shifting and deposition of sediments and unstable lake level. All primary events in the reservoir food chain seem to be greater in the delta waters and, therefore, it may be the most productive area in the reservoir.

Since Lake Texoma was built to retain extreme runoff that occurs infrequently, water levels in the reservoir have been kept low enough to prevent significant erosion of the delta by wave action. The depositional nature of the delta is enhanced by the propensity of the Red River to deposit large volumes of sediments during these infrequent floods (i.e. some flooding occurs annually, usually in spring, but high flows eventuate every 2-3 years). Thus, fluvially-derived lands have continuously been recruited and biotically colonized since the reservoir was built and should be considered a significant ecological resource.

FLATHEAD LAKE, MONTANA

Pleistocene glaciation created oligotrophic Flathead Lake, although deposition of sediments by its feeder stream has since created an exposed delta and associated shallows at the upstream end of the Lake. The Flathead River drains easily erodable precambrian sediments of the Glacier National Park--Bob Marshall Wilderness area of northwestern Montana. The river carries a mean flow of ca. 6000 cfs into Flathead Lake, but spring runoff annually increases flows to ca. 60,000 cfs; flood flows exceeding 100,000 cfs have been recorded twice since 1900.

Natural hydrodynamics in the Lake, therefore involved a spring rise to flood pool accompanied by extensive sediment deposition on the delta. The spring rise was enhanced by a constriction at the outlet of the lake, but water levels subsided by August in most years. Sediments were deposited on the delta during short-term flood periods in spring and were largely unaffected by wave action the rest of the year. Thus, settlers found a well-stabilized, wooded delta fan in the river end of the Lake. A variety of wildlife utilized this delta habitat, notably ospreys (*Pandion haliaetus*) and bald eagles (*Haliaeetus leucocephalus*). A Federal wildlife refuge incorporating the delta was established to protect these valuable species.

In 1937, however, a hydroelectric dam was built at the outlet to permit ca. 3m (10 ft.) regulation of lake level. Operation of the dam is such that spring floodwaters are now retained in the Lake and gradually discharged during fall and winter. Maintenance of high water has promoted wave erosion on the delta to the extent that at least 3 km^2 of stabilized lands have receded downslope and are continuously under water (Dr. Johnnie N. Moore, University of Montana, unpubl. data).

The altered lake level regime facilitated by Kerr Dam has destroyed Federally-owned wildlife habitat. Only fragments of the original delta fan remain, but one bald eagle and several osprey nests are yet utilized. In spring, 1979, three offspring were reared by the eagles. At present, erosion rates at the nest site cannot persist more than 1 or 2 years. Whether or not such losses should be mitigated by those who operate the dam, is open to question.

CONCLUSIONS

Delta formation in reservoirs may be considered beneficial from the standpoint of wildlife enhancement. Depositional processes described for Lake Texoma are evident in nearly all reservoirs where water levels have, by chance, been held low enough to promote delta formation (e.g. Eufala Reservoir, Oklahoma). Detailed study of reservoir operation and existing ecology of delta proliferation may reveal management tactics that could enhance utilization of delta wetlands by wildlife (e.g. periodic seeding or flooding programs).

The increasing need for hydropower may have an influence on how reservoir water level is managed in the future. For example, if higher water levels were sustained in Lake Texoma to facilitate greater power production, the existing depositional delta could well be changed to an erosional system promulgated by wave action. Like the Flathead Lake situation, such loss of wildlife habitat should at least be questioned, if not mitigated.

ACKNOWLEDGEMENTS

I thank Dr. Johnnie Moore, Montana, and Mr. Tom J. Stuart, Flathead Research Group, for bringing the erosional problems in Flathead Lake to my attention. Thanks also to Dr. James V. Ward, Colorado State University, for help with the manuscript.

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Mitigation Planning Under the Principles and Standards[1]

Leonard Shabman[2]

Abstract - Recent water policy reforms stress improved mitigation planning through improved economic and environmental assessment and stricter application of the Principles and Standards decision framework. While there are practical limits on the use of the assessment tools being developed, the result will be improved mitigation analysis and increased mitigation at Federal projects.

BACKGROUND

The Fish and Wildlife Coordination Act (FWCA) requires that negative effects on wildlife habitat be fully considered in multipurpose water resources project planning [FWCA]. For each project the Secretary of Interior is to prepare a report which will "describe the damage to wildlife attributable to the project and the resources proposed for mitigating or compensating for these damages" [FWCA, 662(a)]. In response to Interior's report, the lead planning agency "shall give full consideration to the report and recommendations ... and shall include such justifiable means and measures for wildlife purposes as the reporting agency finds should be adopted to obtain maximum overall project benefits" [FWCA, 662(b)].

Under the guidance offered by this language water resource agencies (primarily the Corps of Engineers and Bureau of Reclamation) have entered into a project by project negotiation process with the Fish and Wildlife Service (FWS) and the National Oceanic and Atmospheric Administration (NOAA)[3] to establish necessary mitigation measures to lessen fish and wildlife losses at Federal projects. The results of this process have been called into question in recent years with critics charging that the amount and nature of mitigation implemented in the past has been inadequate. [GAO, 1974; NWF, 1977]. The practical effect of this criticism can be found in President Carter's water policy message which stressed the need for increased consideration of fish and wildlife habitat in the net benefit and environmental analyses conducted under the Principles and Standards (P&S) [U. S. Water Resources Council, 1973]. In addition, he called for more vigorous compliance with the spirit of the FWCA.

The P&S establishes that water resource plans are to address the twin objectives of National Economic Development (NED) and Environmental Quality (EQ). The goal of the (P&S) is to encourage the display of trade-offs that must be made between objectives as plans are modified, so that decision makers will have an improved information base for choosing among alternative plans. In order to fully display the range of choice available, the P&S calls for development of a single plan which optimizes NED. It then requires development of a series of plans which emphasize EQ. In his water policy message President Carter reaffirmed this basic structure of the P&S as a decision tool, but noted that the application of the P&S had been incomplete on some projects and inconsistent between projects, especially for NED analysis. In order to insure that the P&S is "scrupulously adhered to in the planning, review and implementation of Federal water resources projects" [Carter, 1978] he called for publication of a manual of procedures that could insure proper evaluation of National Economic Development (NED) benefits and costs (hereafter referred to as the "manual") [U.S. Water Resources Council, 1979]. Included within this manual are procedures to insure improved "assessment and consideration of costs [NED] of elimination of ... wetlands [and] wildlife habitat ... " [Carter, 1978].

Elsewhere in his message the President called for publication of regulations to insure compliance with the mitigation requirements of the FWCA (hereafter referred to as the "FWCA regulations") [Interior]. In particular he calls for "acceptable methods for determining adequate measures to prevent or mitigate losses of fish [and] wildlife ... " [Carter, 1978].Regulations were published in draft form on May 18, 1978 and are consistent with a P&S framework for mitigation planning. More specifically, the FWCA regulations strengthen the requirement that the EQ loss (here wildlife habitat) be considered on an equal basis with other project purposes both within the NED account and as a tradeoff between NED and EQ.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 19, 1977.

[2] Associate Professor, Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA.

[3] In previous years different agencies may have been involved.

The FWCA regulations also require that mitigation planning focus primarily upon replacement of "wildlife resource productivity" [Interior, p. 29310]. The Habitat Evaluation Procedures (HEP)being developed by FWS are probably intended to be the analytical tool for use in defining "wildlife resource productivity", although HEP is not mentioned in the FWCA regulations [PIET, 1979]. The development of HEP began in 1970 for use within the EQ account of the P&S [Schamberger & Farmer, 1978]. Simply described HEP can be used to measure the number of "habitat units" gained or lost due to a project. Habitat units are the product of the size of the area and the quality of the habitat type within the area. Habitat quality, in turn, is determined by the number of different species supported by an area and the characteristics of the area such as cover type and available food and water. [HEP]

CRITICISMS OF CURRENT MITIGATION PLANNING

In the past, the lead agency justified the nature and extent of its mitigation recommendation by the need to replace lost fishing and hunting recreation days and/or commercial fishing and trapping opportunities. A monetary use value of these recreational and commercial opportunities was developed and complete mitigation was said to occur when the monetary use value of recreational and commercial opportunities provided by the project, with its specific mitigation measures, equalled the monetary value of the opportunities lost. If the incremental costs of mitigating exceeded the incremental value of the opportunities replaced less than full mitigation was recommended. Two criticisms of this approach have been made. First, the techniques for establishing the NED value of the without project condition were criticized for being conceptually unsound and/or poorly implemented. For example, the unit day values published in the P&S and used to value foregone recreational opportunities have no conceptual foundation in economic valuation theory. [Dwyer, et al., 1977] Other NED valuation tools often proposed and utilized by wildlife agencies such as gross expenditures on recreation habitat replacement cost, or use of energy accounting were equally invalid [Thomas, et al., 1979]

A second criticism of the traditional mitigation analysis is based upon the argument that complete replacement of physical habitat was the intention of the FWCA; as such, the traditional mitigation planning process, based upon replacement of recreational and commercial use value, is not in compliance with FWCA [NWF, 1977]. However, this criticism is based upon a somewhat liberal interpretation of the legislative history of the FWCA [NWF, 1977, p. 9]. On the other hand it is not clear that only the replacement of recreational and commercial use value was the intent of the FWCA. In fact, the FWCA is not all precise in its intent. This leads to the plausible conclusion that the Congress intended that the choice of analytical tools for mitigation planning and determination of mitigation levels at any project be determined by negotiation between the affected agencies.

The recent draft publications of the manual, the FWCA regulations, and HEP are all products of this negotiation process which address the criticisms of past practices. First, the conceptual validity of the NED habitat valuation may be improved by the manual. Second, the debate over the intent of FWCA has been made moot by the President's reaffirmation of the P&S requirement to conduct NED and EQ analysis, by the publication of the FWCA regulations, and by the development of HEP. These occurances, taken together will improve the negotiation process for establishing mitigation levels. The range for negotiation will be narrowed by establishing a concensus on the proper evaluation tools for NED and EQ mitigation evaluation and by better establishing minimum levels of mitigation. The following discussion indicates how this is intended to occur.

THE INTENDED CHANGES IN MITIGATION PLANNING

In order to illustrate the mitigation planning and negotiating process intended to occur in the future, this discussion will consider a hypothetical water resources project which floods existing wildlife habitat. This results in a loss to society of time stream of habitat unit (as defined by HEP) benefits, in both an NED and EQ context. The action agency causing the loss must, under the P&S, develop a plan to optimize NED and will do so under the guidance of the manual. Within the manual the present value of the current and future habitat users willingness to pay for these services rather than go without them is used to measure the opportunity cost of destroying the habitat which exists without the project. The opportunity cost is then charged to the project. The action agency can reduce this cost by mitigating the habitat loss in one of two ways: (1) alteration of project design or operation, such as changing project size, location, operating rules, or timing of construction phases; and (2) acquisition and management of lands near the project or more intensive management of lands already in public ownership. These mitigation efforts will result in two types of mitigation costs: (1) foregone NED net benefits as plans are modified in the interests of mitigation; and, (2) direct financial outlay for mitigation measures. The optimal NED plan is achieved when the sum of opportunity costs plus mitigation costs is at a minimum. This sum will be called "total habitat costs" for purposes of discussion.

Consider this NED analysis in the context of Figure 1. At point 0 a fixed number of habitat units, OA, are lost due to a public plan. Movements toward A represent increasing levels of mitigation defined as replacement of habitat units. Within Figure 1 are two projects I and II, with the NED value II > I prior to consideration of mitigation. Both I and II result in OA habitat units lost. Let the distance OC be the net benefits foregone from choosing I over II when mitigation is not considered. The line segment CD shows this to be constant as mitigation increases. Acquisition and management costs for increased mitigation levels are OJ for project I and GH for project II. If project II is pursued GH indicates the costs for increasing levels for mitigation. If project I is pursued, instead of II, mitigation costs are OJ plus CD which is equal to CE. Least cost mitigation for any mitigation level beyond 0 is the lesser of the costs along GH or CE; this is the line segment CIH. Each point on CIH depicts both the level of expenditures for management and acquisition and a choice between projects I and II. Each point, in turn, can be viewed as a different plan for consideration in the P&S process.

Also depicted in Figure 1 is the opportunity cost curve which shows that as more units of habitat are replaced the values foregone are reduced. This curve is shown as BA. Summation of BA and CIH is the total habitat costs curve, QH. In Figure 1, OZ is the optimal mitigation level and the plan associated with OZ is the optimal NED plan. This is the minimum point on the total habitat costs curve. Movements in either direction away from OZ result in lower NED net benefits.

Two important points can be derived from the discussion to this point. First, the optimal NED plan will almost always include some mitigation based upon the NED criterion alone. In fact, estimation of the curves shown in Figure 2 will establish minimum levels of mitigation. However, these curves must also be estimated so that the appropriate habit costs of any plan can be included in a net benefit analysis. These costs will include any uncompensated opportunity costs of the without project condition and direct financial outlays for mitigation measures (taken from GH or OF in Figure 1). Note that these costs do not include foregone NED net benefits resulting from project design or operation changes (CD in Figure 1). This is done because proper accounting procedures will only reflect costs of the with vs. without project situation, not between project alternatives. In Figure 1, opportunity costs of OF and an amount equal to the direct financial outlay (also OF) needed to achieve OZ will be included in the net benefits calculation for any plan.

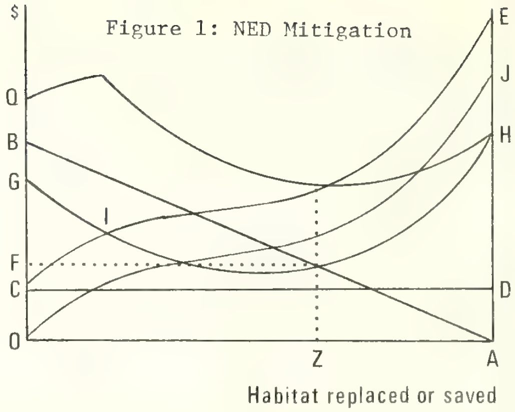
Figure 1: NED Mitigation

However, under the P&S framework mitigation planning cannot stop with the NED mitigation level since the P&S also calls for the display of plans which emphasize EQ. A plan which emphasized EQ would propose mitigation beyond the NED minimum. This would increase total habitat costs (reduce NED), but retain physical habitat units (more EQ) which would otherwise have been lost. This can be more clearly illustrated in Figure 2.

In Figure 2 OB is a transformation curve showing the tradeoff between NED and EQ (Habitat units) for alternative water resource management plans. At point A, NED benefits for the project are at a maximum. The segment OA is irrelevant in the decision process since it shows that mitigation serves both the NED and EQ objectives. (OA corresponds to mitigation levels to the left of point Z in Figure 1). The segment AB (OZ' is 100% replacement) indi-

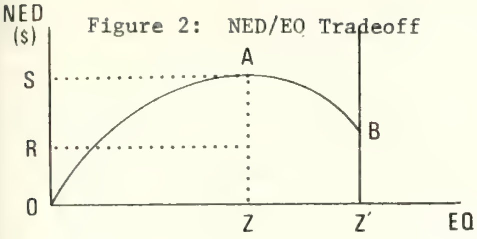

Figure 2: NED/EQ Tradeoff

cates that some NED must be foregone to serve the EQ objective by mitigating at levels higher than OZ. Between A and B is the zone of "rational" mitigation for the negotiation process. For example, a choice can be made to choose the plan which provides OZ' mitigation and give up RS of NED benefits in order to retain habitat units, ZZ'.

The P&S requires that the plan with the NED mitigation level (OZ in Figure 2) be displayed. On the other hand the FWCA procedures, as currently drafted, require that the wildlife agencies prepare a mitigation plan with " ... measures required to replace ... [the habitat] loss (if that is possible) measured without reference to values attributed to human use ... or other monetary computations" [Interior, p. 29309]. In response to these wildlife agency proposals "action agencies are required to make findings on [the justification for] wildlife conservation measures ... using assessment and evaluation techniques based upon wildlife habitat values. Monetary values ... shall not be used for justification purposes." [Interior, p. 29310]. In this statement of findings the action agency may not reject recommendations for mitigation solely on the basis that the measures will reduce net benefits of the project [Interior, pp. 23910 and 29311]. Rather, if the wildlife agency recommendation is rejected the action agency must explain hos this rejection is necessary "for obtaining maximum overall project benefits" [Interior p. 29311].

The reference in the FWCA regulations to overall project benefits can be interpreted as a recognition of the tradeoff format established in the P&S. Nonetheless, since the tradeoff process is based upon interagency negotiation within the P&S planning process, it is important to note that the FWCA procedures can alter the results of that process. The requirement to "replace [habitat] loss (if that is possible)" can be interpreted as extending the starting point for the negotiation process to establish mitigation levels to the right of OZ in Figure 1. As a result, the burden of proof is on the action agency to justify movements back toward OZ. Such justification will have to be established on the grounds that foregone NED benefits of more complete mitigation are unacceptably large in the broader social welfare context represented by the dual objectives of NED and EQ. This is a marked departure from current practice where the agencies normally would not recommend mitigation levels beyond OZ. Interagency acceptance of the procedures, as currently drafted, will therefore alter the initial bargaining position that must be adopted by the agencies and may result in significant changes in mitigation choices made in the future.

OBSTACLES TO IMPROVEMENTS IN MITIGATION PLANNING

The process described above depends upon conceptually sound NED and EQ analysis. The manual is to provide guidance for NED analysis and HEP is to serve a similar function for EQ. The following discussion will assess the "state-of-the-art" in application of NED and EQ analysis. The focus of the NED discussion will be entirely upon the recreational values of habitat. Other habitat services (ex groundwater recharge) may exist but these are not relevant to FWCA [Thomas, 1979].

Conceptual basis for NED habitat valuation: At least two conceptual advances in NED valuation of natural environments have expanded the basis for valuation beyond the limits imposed by willingness to pay (WTP) of direct habitat users. First, there is a professional concensus that willingness to accept compensation (WTA) measures of economic value may be more appropriate than WTP measures for certain natural environments, based upon a presumption that ownership rights to natural habitats are vested in current and future users [Freeman, 1979; Krutilla and Fisher, 1976]. The WTA analysis identifies the level of compensation required by the current owners to induce them to give up habitat ownership. This is a different starting point than the situation where the ownership is vested elsewhere and the analysis asks what the WTP of the habitat user would be to reserve it from development. The distinction is important since WTA measures of habitat value will tend to be higher than WTP estimates.

A second conceptual advance is the demonstration that the WTP (or WTA) of direct users of a natural environment is not the only basis for value. When habitat destruction is irreversible, and there are no (or few) substitute ways to provide the habitat services, option values exist for non-users who are less than certain about their future use of the habitat. [Chichetti and Freeman, 1971]. The same non-users may also value the existence of the resource even when they have no expectation of future use. [Krutilla, 1967]. These option and existence values are additions to WTA or WTA measures of value to present and future users.

As currently drafted, the manual is based upon application of more traditional techniques designed to measure WTP of direct users. As such, there is reason to argue that the conceptual base of the manual may understate the value of habitat, even when properly applied.

Methods for NED habitat valuation: Since habitat services (or their close substitutes) are not traded in the market, shadow pricing techniques must be employed to measure the value of the services provided. However, the dearth of market information and the difficulty of conceptually sound interpretation of the limited data which is available, make use of these techniques difficult. Consider the recreational values derived from wildlife habitat. The manual identifies travel cost (TC) and contingent valuation (CV) methods as of superior merit for evaluating the recreational values attributable to habitat.[4] The TC method establishes value of a recreational site by examining individuals' travel expenditures to use the site; however, the TC technique can not measure values for a particular site characteristic (ex. habitat quality), but rather measures the value of the total recreational experience. The CV method allows individuals to bid for specific attributes of an experience (such as a habitat service) in a hypothetical market, but whether there is a bias in such bidding games is a matter for further research.[5] [Randall and Brookshire, 1973].

Regardless of analytical method used, proper NED analysis will depend upon acquisition of new levels of sophistication by field planners in their understanding of both the conceptual foundations of NED and methods of evaluation. It is highly doubtful that such sophi tication will be immediately achieved in the field and the manual will not, in its current form, fill that need for basic education. In addition, the scope and detail of analysis will require planning funds far in excess of those now utilized in the NED habitat valuation process. In an attempt to reduce these planning costs and resolve the problem of lack of field expertise, the manual encourages the use of regional models to do project specific studies. These models can be developed by a central authority (ex. FWS) and then made available for field use. The problem is that regional models are not now available and are not likely to be available in the near future. Even if they are, many of the conceptual issue above may remain open since the models will reflect the limited NED analytical scope of the manual.

Clearly NED analysis in the near future will provide less than complete measures of NED value. There is also reason to expect that the quality of the analysis will be variable and hence a focus of debate. In any even, NED analysis will be done and it should assist the decision process in establishing approximate NED mitigation levels and provide estimates of costs to be included in the net benefit analyses.

HEP Procedures - Some Limitations:[6] HEP application requires the exercise of judgment by the analyst (1) to determine the quality of habitat being lost and the management needed t replace that habitat, and, (2) to identify "acceptable" substitute habitats when exact replacement is not possible. While the variable to be used for determining habitat quality are discussed in HEP, the measurement of the variables and the parameters used to aggregate the measurements into an index value depend upon the judgment of the analyst.

An appropriate analogy to the HEP process is found in the real estate appraisal process. The appraiser utilizes his knowledge of the market and the property in question to estimat a likely market value for the property. The land appraiser may turn to some quantitive data, such as comparable sales, for guidance but the final value estimate is based upon his best judgment. HEP is a similar "appraisal" tool for judging wildlife habitat.

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[4] An emerging technique is the conceptually sound interpretation of household expenditure data through a hedonic price technique. This is not a highly developed tool and is not now one of the methods suggested by the manual [Thomas, 1979].

[5] In order to use TC or CV methods to derive a use value for a specific habitat unit, "production" linkages between habitat quality and species numbers and diversity must be known. HEP may provide some help here. Then, "transformation" linkages between species number and diversity and the utility of the recreational experience must also be known. The manual assumes knowledge of these production and transformation functions and therefore assumes away a major analytical problem. See: [Thomas, 1979; Shabman, Batie and Mabbs-Zeno, 1979].

[6] This discussion is limited in scope. Ot er problems for P&S application of HEP need t be resolved, including the proper accounting stance, the role of discounting and the specification of the with and without project conditions.

This does not suggest that HEP is an unsatisfactory analytical tool. It does suggest that analysts may differ over the EQ values of the without project habitat and "necessary" mitigation measures for its replacement. This situation will be exacerbated by the current lack of field expertise in the use of HEP techniques. Without an unambiguous definition of EQ habitat value, the P&S decision framework depicted in Figure 2 can only be imperfectly implemented.

The current state of the HEP procedures also creates a barrier to improved NED mitigation planning. HEP does not provide guidance for establishing the relationship between habitat management practices and habitat units produced. As such, there is little basis for establishing a function relating management costs to habitat units replaced (GH and OJ in Figure 1). Without this information, identification of the least cost mitigation strategy (CIH in Figure 1) will be made difficult and, as such, so will identification of the NED mitigation level.

CONCLUSIONS

Recent water policy reform proposals may change the bargaining strength of the wildlife agencies when mitigation levels are negotiated. This will result from several separate changes in the approach to mitigation planning and evaluation including: (1) A recognition that NED plans will almost always have some level of mitigation; (2) A requirement for full inclusion of habitat costs in the net benefits analysis. These habitat costs include both direct expenditures for mitigation and a fuller accounting of the foregone NED habitat values of the without project condition; (3) A shift from wildlife agencies needing to justify why there should be more mitigation than the development agency proposes, to the development agency needing to justify why there should be less mitigation than the wildlife agency proposes; and, (4) a clearer focus for the agency negotiating process since the acceptable tools for mitigation evaluation and the range of acceptable mitigation choices are more precisely defined.

However, the limits of NED and EQ analysis will interfere with the achievement of an ideal mitigation planning process. Indeed, the agency negotiation process for mitigation planning is often likely to revolve around the "scientific" validity of the NED and EQ analysis and not simply the issue of how much mitigation is "justified". This point must be recognized, although the FWCA procedures and the manual reflect an expectation of a more precise analytical resolution of mitigation questions. If the analytical disagreements are not to obscure the fundamental changes being sought, an interim decision process, which recognizes the limits of measurement, needs to be established. However, this process should still preserve the tradeoff framework of the P&S. A reasonable interim process would be to adopt a "social opportunity cost" decision framework for mitigation choice making. In its simplest form the approach would be to offer decision makers a menu of choices relating the level of habitat unit replacement to the costs of that replacement (CIH in Figure 1). Then, the decision to be made is "are the costs of habitat replacement (or saving) unacceptably large?" Obviously, this must be a value judgment but the decision focus provides a framework for addressing the issue. In fact, this approach has been proposed elsewhere in different contexts [Bishop, 1978; Shabman and Bertelson, 1979]. Some considerations that could enter into making this decision are: (1) Are WTA measures of value more appropriate than WTP in this case and is WTA likely to larger the WTP? (2) Are option and existence values likely to be significant for the habitat in question? (3) Are there likely to be EQ values which escape NED concepts for measurement? These may include recognition of the value of the habitat in an ecosystem context rather than only for the direct services to man the habitat provides [Shabman, Batie, Mabbs-Zeno, 1979]. Affirmative answers to the questions may suggest that society would be more willing to incur the costs of relacing (saving) habitat.

Even with this approach much more research work on HEP must be done. A better understanding of the social opportunity cost function can only be achieved if we better understand the relationship between management costs and habit replacement. Research to improve the measures of NED habitat value are necessary in order to properly charge full habitat costs to the net benefits analysis and to establish a minimum (NED) mitigation level. However, analysts and policy makers both need to be careful that they don't require quantitative measurement that is beyond what is now possible in the field. Analysts should measure only what can now be done well, while leaving areas where quantitative measurement tools are in a primitive state for more explicit decision making. As Steiner has observed with respect to the role of measurement in decision making "... it may be better to be vaguely right than precisely wrong" [Steiner, 1969, p. 42].

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Principles and Standards Planning, Chikaskia River Basin, Kansas, with Emphasis on Fish and Wildlife Habitat Mitigation Achieved[1]

Stephen Capel[2]
and
Jim Lutey[3]

Abstract.--Case history of the application of Principles and Standards planning--Chikaskia River Basin, Kansas. Bureau of Reclamation water supply project for Wichita, KS. NED Plan was reservoir; EQ Plan was preservation of river corridors and optimum stream flows (Chikaskia River is the only wildlife habitat in a "sea of wheat"). Recommended Plan was reservoir with 16 miles of river corridors and 10,000 acre-feet of water storage for downstream releases. Terrestrial mitigation adequate; somewhat lacking for aquatic losses.

INTRODUCTION

A feasibility study of the Chikaskia River asin was authorized in response to Public Law 9-561, 89th Congress on September 7, 1966. ongress appropriated funds to the Bureau of eclamation to initiate the investigation in ctober 1973. The scope of the investigation as to evaluate the water resources of the hikaskia River, primarily for municipal and ndustrial use for the city of Wichita. Project urposes also included flood control, recreation, nd fish and wildlife. Prospective solutions o be explored included a dam and reservoir n the Chikaskia River near Corbin, Kansas, long with alternative sites. Alternative plans ere to be analyzed using multiobjective plan-ing procedures in accordance with the Water esources Council's "Principles and Standards."

This paper briefly describes a classical rinciples and Standards" investigation and ocuses on the resultant values of such planning ncluding the mitigation of fish and wildlife esource losses.

STUDY AREA

The Chikaskia River Basin comprises approxi-tely 2,092 square miles in southcentral Kansas and northcentral Oklahoma (fig. 1).

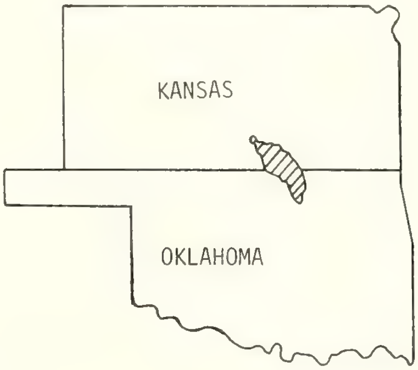

Figure 1.--Chikaskia River Basin, Kansas-Oklahoma.

The Chikaskia River and adjacent riparian vegetation is an island of quality fish and wildlife habitat in a "sea of wheat" (fig. 2). Cropland represents about 72 percent of the entire Chikaskia Basin with wheat the dominant crop grown (93 percent). Year after year, Sumner County (location of the recommended project plan) is the leading wheat producing county in Kansas, with about 78 percent of the County intensively cultivated.

The Chikaskia River is a flat sandy-bottomed stream with excellent water quality (fig. 3). Thirty-five species of warm-water fish have been collected in the Chikaskia River. The standing crop of fish averaged about 166 pounds per acre-foot, making it a quality fishery, rarely surpassed in Kansas. The Kansas Park and Resources Authority in their Scenic Rivers and Streams Study identified the Chikaskia River as the most outstanding stream in 31 counties of southwest Kansas.

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[1] Paper presented at The Mitigation Symposium, . Collins, Colorado, July 16-20, 1979.

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[3] Area Supervisor, Fish and Wildlife Service, Kansas City, Missouri.

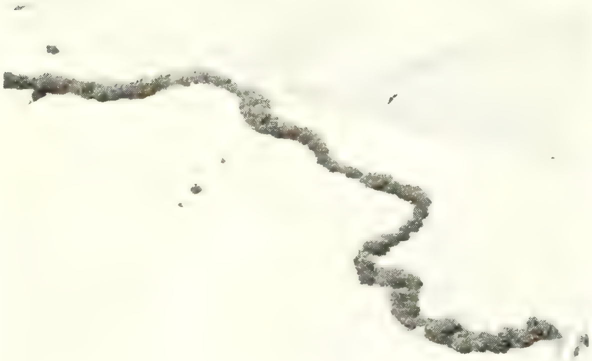

Figure 2.--The riparian habitat of the Chikaskia River Basin constitutes the only quality wildlife habitat in what is otherwise a "wheat desert." Even the road ditches are intensively farmed.

Figure 3.--With a standing crop of over 150 lbs/acre-foot, the Chikaskia River supports one of the best fisheries in the plains states.

Riparian timber and native grasslands along the Chikaskia River provide a valuable ecosystem for a variety of wildlife, including white-tailed deer, Rio Grande turkey, bobwhite quail, mourning dove, fox squirrel, cottontail rabbit, raccoon, mink, muskrat, beaver, opossum, coyote, red fox, herons, various raptors and other non-game birds, rodents, reptiles and amphibians (fig. 4). Other habitat types include native grassland pastures, hedgerows, and cropland.

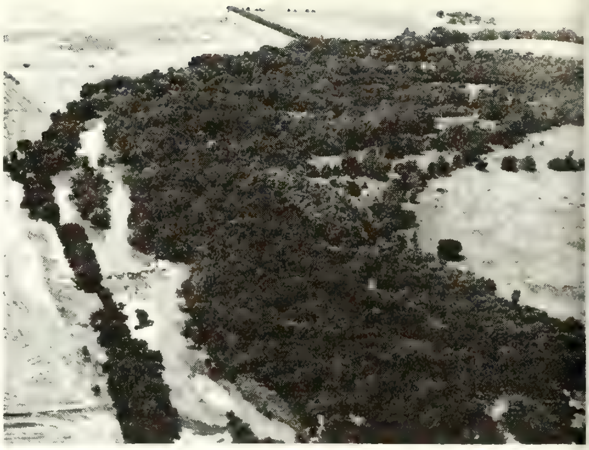

Figure 4.--Without the riparian habitat of th Chikaskia River, Sumner County would loos its deer herd and the majority of the squ rels and furbearers.

PLAN FORMULATION

Principles and Standards

The Chikaskia Project investigation was one of the first feasibility studies conducte in accordance with the Water Resources Counci Principles and Standards (P&S). The investigation was "classical" since P&S was the majo guidance for the study, and all involved agen were dedicated to the planning process. Agen and groups actively involved in the planning process included the Bureau of Reclamation, U.S. Fish and Wildlife Service, National Park Service, Corps of Engineers, Kansas Water Resources Board, Kansas Fish and Game Commissio Kansas Historical Society, Kansas Parks and Resources Authority, Oklahoma Water Resources Board, Equus Beds Groundwater Management District #1, Wichita-Sedgwick County Metropolita Planning Department, City of Wichita, City of Wellington, Chikaskia Regional Planning Commission, Chikaskia River Association, Chikask Landowners Association, Sierra Club, and Wich Audubon Society.

The feasibility study was initiated in ea 1974 with the formation of a steering committ (composed of federal, state and private organ zations), an NED task force, and an EQ task force (each with a chairman). The purpose of these committees and teams was to promote "in agency multidisciplinary planning" as much as possible and to consider NED and EQ as equal national objectives. This is not to say that the whole planning process was perfect and pr gressed smoothly. There were many difficulti along the way, however, in retrospect, the feasibility study was truly a "Principles and andards" study.

The first portion of the investigation consted primarily of data gathering. The EQ sk force consulted the University of Kansas ace Technology Center which provided an acree breakdown of land use and a stream order p of the Chikaskia River Basin. The Fish d Wildlife Service and Kansas Fish and Game mmission conducted terrestrial habitat evaluions (HEP) in the basin in November and Decemr 1974. The Kansas Fish and Game Commission nducted standing crop fishery evaluations in e basin during the summer and fall of 1974. became obvious that the Chikaskia River, s major tributaries, and the adjacent riparian getation was the only decent wildlife habitat the entire basin (fig. 2).

These early evaluations gave the EQ task rce a good picture of the problems and needs the Chikaskia River Basin and enabled the sk force to set realistic EQ objectives. ecific EQ objectives included accelerating oper land-use techniques, acquiring corridors preserve and maintain the natural resources ong the Chikaskia River, protecting stream ows for the Chikaskia River, and eliminating wing of road rights-of-way. NED objectives cluded a municipal and industrial water supply r Wichita and Wellington, Kansas, flood proction to agricultural lands and Blackwell, lahoma, recreation, and fish and wildlife.

Alternatives were developed to satisfy the udy objectives, primarily a water supply for chita. Several reservoir sites and increased ound water withdrawals were studied in detail. her alternatives such as utilizing existing servoirs, a combination of existing reservoirs d ground water withdrawal, and water consertion were not thoroughly studied.

A surface reservoir site on the Chikaskia ver near Corbin, Kansas, was the alternative at was given the most attention by the Bureau Reclamation. It soon became obvious that is was the preferred NED Plan.

NED Plan

The NED Plan is Corbin Dam and Reservoir 2,600 surface acres) and a 40 mile aqueduct stem which would carry 55,400 acre-feet of nicipal and industrial (M&I) water to the ties of Wichita and Wellington, Kansas. The) Plan also includes:

Wildlife management on 8,500 acres of project lands (mostly cropland).

Acquisition of 380 acres of additional land for wildlife mitigation.

3. Downstream water releases from the sediment pool storage. The initial year release would be 14,300 acre-feet, and the amount would gradually decrease to no available water for release at the end of 100 years.

The NED Plan, however, does not include adequate compensation for fish and wildlife losses.

EQ Plan

The Environmental Quality Task Force formulated an EQ Plan based on identified problems and needs and EQ objectives to satisfy those needs in the Chikaskia River Basin. A "Pure EQ Plan" was developed irrespective of satisfying NED objectives, i.e., water supply and flood control. The major features of the "Pure EQ Plan" are:

1. A demonstration farm to demonstrate proper land-use techniques for reducing erosion, improving range conditions, improving wildlife food and cover, proper use of pesticides, and for educational purposes.
2. Stream corridors to preserve and enhance natural, scenic and recreational values.
3. Preservation of archeological and historical resources.

The EQ Task Force also developed an EQ Plan with Corbin Reservoir which would satisfy major NED objectives. This "Reservoir EQ Plan" was Corbin Dam and Reservoir with all other features of the "Pure EQ Plan" (as described above). The "Reservoir EQ Plan" also included measures to compensate for fish and wildlife losses. Primarily, this included a 3,800-acre corridor along the river below the reservoir for fish and wildlife management and adequate downstream releases below the dam for the life of the project.

Recommended Plan

The Recommended Plan includes Corbin Dam and Reservoir as described in the NED Plan. In addition, the Recommended Plan includes a 2,640-acre corridor along the Chikaskia River below the dam and a 950-acre corridor along the river above the reservoir (fig. 5). The Bureau of Reclamation identified these corridors as a "Joint Fish and Wildlife and Environmental Quality (EQ) Feature" and included it as a nonreimbursable federal cost. The Recommended Plan provides for fencing, initial development costs and annual operation and maintenance costs along the corridors for fish and wildlife management. It is the inclusion of the corridors in the Recommended Plan that provides adquate

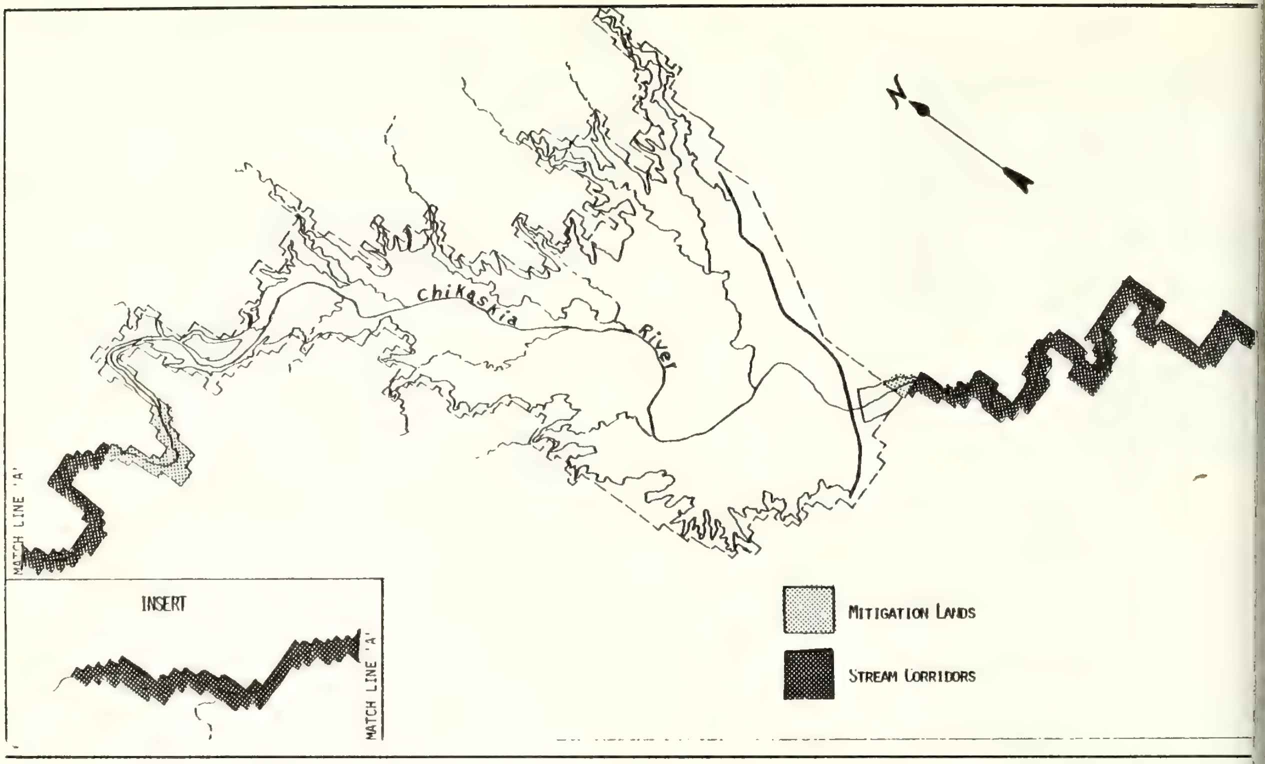

Figure 5.--The Recommended Plan combines the reservoir (NED) and river corridors (EQ) as the two major features. Terrestrial compensation is closely approximated, but aquatic losses are not adequately compensated.

compensation for terrestrial wildlife losses.

The Bureau of Reclamation supports the concept of the demonstration farm in the Recommended Plan, however, does not include it as a Bureau financed feature associated with the development of the municipal water supply project. The Bureau maintains that the demonstration farm should be funded by local or state entities.

VALUE OF PRINCIPLES AND STANDARDS PLANNING

One of the main values of P&S procedures is the emphasis on examining all alternatives, structural and non-structural. By drawing a variety of people from diverse backgrounds together for the Task Forces, many different ideas and potential approaches are brought to light. Some alternatives are mandated in the planning process, and some are obvious outgrowths of the backgrounds of the participants; however, local participants are often aware of potential solutions which distant experts are not.

P&S planning provides specifically for the examination of many alternatives in the initial stages. In the past, alternatives have often arisen too late in the game. Once detailed planning was underway, construction agencies were usually reluctant to stop to consider n alternatives. As participants become famili with the workings of P&S procedures, alterna ve to major construction should be more favorab presented and considered.

Another value of P&S planning is that de sion-makers have all of the environmental an economic account items and trade-offs highli te for them. They can get the full picture of the Recommended Plan and what will be lost a gained through the proposed project. It giv everyone a chance to present their case in t open.

Perhaps one of the least recognized and most valuable benefits of P&S planning is th there are no last minute surprises. The Tas Forces have been working closely together wi frequent coordination meetings. If everyone has taken the job seriously and carried it o properly, everyone knows where the group is headed, what has been done, and what will be proposed. This value is not to be downplaye particularly if you have ever had any experi ce in other planning processes. If any snags ar e, everyone knows about it at the same time. W le the whole group will never be in complete agreement, all opinions are heard, and you know which branch of the road has been taken.

UNRESOLVED PROBLEMS

Several basic differences remain to be resolved. The Bureau of Reclamation maintains that mitigation should be based on man-days. The Fish and Wildlife Service (and most state wildlife agencies including Kansas Fish and Game Commission) maintains that lost or damaged habitats are the basis for mitigation. We feel the Habitat Evaluation Procedure (HEP) is the best approach to measure habitats for mitigation purposes.

We really doubt if the differences are as much philosophical as economic. In the case of the Chikaskia Basin and Corbin Reservoir, the Bureau of Reclamation essentially provided full compensation in the Recommended Plan. Only a small area (380 acres) was ascribed in the Recommended Plan as mitigation (based on man-days compensation). The remaining compensation was in the form of river corridors (3,590 acres) as a "Joint Fish and Wildlife and Environmental Quality Feature." This approach, while providing an equivalent to full terrestrial compensation allowed the Bureau (Federal Government) to absorb the bulk of the mitigation cost. Thus the expense to the local sponsor was considerably reduced, making the project much more palatable to them. This approach reduced mitigation costs to the local sponsors by some 90 percent. Man-days are cheaper to mitigate than habitats, because man-days of use increase significantly by changing from private land to public ownership. This approach does not improve the welfare of the wildlife involved.

There remains a problem in providing for adequate downstream releases to sustain the downstream aquatic ecosystem. At Chikaskia, the allotment of water for release is from the sediment pool storage. This means a decreasing quantity of water will be available as time goes on and as sedimentation occurs. There will be adequate water at first--but none by the end of the project. Future generations are being shortchanged. Kansas water right laws do not recognize instream flows for fish and wildlife purposes, and the Bureau maintains this was an institutional obstacle for providing downstream releases. However, it would be possible for the Kansas Water Resources Board to enter into an agreement with the Federal Government to assure storage for downstream flows for fish and wildlife.

In some respects there was not a realistic examination of all alternatives. Not all alternatives received equal attention and study. In this case, ground water appeared to be a viable alternative. The Bureau of Reclamation determined that it was potentially damaging to withdraw any more water from the aquifer, because further withdrawals would exceed recharge rates. However, the Bureau didn't pursue the possibility of the City of Wichita buying up existing water rights because of institutional constraints. Most of the water rights in the area are for urban water supplies (Wichita, Newton and McPherson) and irrigation farming. This region's land can support a viable dryland farming economy. Thus it would have been possible (although perhaps not politically feasible) for Wichita to buy up irrigation water rights. This trade off was never examined, although it was brought to the attention of the Task Force.

DESIRABLE RESULTS

The river corridor feature of the Chikaskia Project achieved substantial terrestrial habitat compensation. Sixteen miles of river habitat varying from 1,500 feet wide downstream (12 miles) to 1,000 feet wide upstream of project influences (four miles) allow adequate riparian habitat of sufficient quality on which to compensate for the lost (inundated) riparian habitat. Funds also were included to provide for the development and management of these habitats to their full potential (to bring them up to a "10" value).

Not only did the Bureau make provisions for funding the development of the river corridor wildlife habitats, they also provided funding for the development of the habitats in the flood pool of the reservoir on 8,500 acres at $20/acre. A further provision of the recommended plan was the funding of $59,200 in annual operation and maintenance costs for fish and wildlife management activities. This is the first time in Kansas that a portion of the burden of annual operation and maintenance has been shouldered by the beneficiaries of the project rather than by the Kansas Fish and Game Commission. We regard this as a significant step forward.

There were a few additional features for fish and wildlife in the Recommended Plan including: provision of a maintenance building and residence for the Area Wildlife Manager, plugging existing road culverts at and below conservation pool to create subimpoundments, installing three stairways on the dam for fisherman access, constructing 15 large brush piles for fish habitat, and fisherman and hunter access areas.

RECOMMENDATIONS

1. There is a need to accept the Habitat Evaluation Procedure or some other form of habitat measure as the basis for mitigation, as opposed to the use of man-days, to which the Bureau of Reclamation still clings.

2. In-kind compensation is necessary for valuable habitats. This was achieved for terrestrial habitat in the Chikaskia Basin Project.

3. Adequate downstream water releases should be guaranteed for the life of the project. Instream flows are vital to the maintenance of an aquatic environment downstream of such structures. Fish have water rights too!

4. Principles and Standards Planning proved to be valuable when all participants honored the full intent and spirit of the guidelines set forth by the Water Resources Council. Perhaps a few refinements are necessary, but it served the purpose well for the Chikaskia Basin.

A Cross-Impact Assessment for Fish and Wildlife Habitats[1]

Ben-chieh Liu[2]

Abstract.--The primary objective of this paper is to analyze, through a welfare model of efficient resource allocation, the value of fish and wildlife habitats as depleting and/or non-renewable capital resources under three major categories: the stock attributes, the flow of goods and services, and the econologically transformed resources through the productive and consumptive process with the flow and the stock input factors. A recreation demand model is employed to illustrate conceptually and empirically how different economic values for these capital resources might be derived or estimated for impact assessment under the National Economic Development Account.

INTRODUCTION

The science of economics deals with the problem of how we can best utilize society's limited resources to satisfy our unlimited wants and promote the general welfare. It is essentially concerned with the identification, allocation, distribution, consumption, and expansion of resources over time so that the overall social well-being and quality of life of human beings can be improved and enriched. In other words, economics is a study to identify what stock of resources is available and what and how goods or services can be most efficiently produced and supplied from this stock per unit of time; who benefits from the consumption of these goods and services and how much is needed to meet basic human needs and satisfy additional human wants; and, finally, how the "stock" of resources and the "flow" of goods and services can be increased relative to the evergrowing number and wants of the human population.

While the issues of the availability, accessibility, utilization, management, conservation, and distribution of natural resources for economic well-being have been among our nation's oldest policy concerns, the application of economic theory to the recreational use and ecological and environmental protection of fish and wildlife habitats in this country is not only a relatively new development, primarily within the last 2 decades, but also raises controversial issues. Probably the greatest impetus to this rapidly growing effort came with the Principles and Standards of the Water Resources Council which established four accounts--National Economic Development (NED), Regional Economics (RE), Environmental Quality (EQ) and Social Well-Being Improvement (SWBI) for project impact assessment and evaluation. While an increasing level of environmental awareness has caused concern for the diminished stock of certain fish and wildlife species, there are conflicting opinions regarding the value of the population stock of fish and wildlife habitats in general and the goods and services flow that the habitats have provided annually in particular, let alone the divergent evaluation of project impacts in these four accounts and the interdependent trade-offs.

Fish and wildlife habitats, either because of their relative scarcity and uniqueness in the preserved natural environment as natural resources or because of the opportunity cost involved in their development as commodity resources, can be and should be evaluated differently among different places, time periods, and beneficiaries. While some authors (Burt and Cummings 1970; Gordon 1954; and Scott 1955) have emphasized the derived benefits from the flow of resources for consumptive use, others (Amacher, Tollison, and Willett 1974; Bachmura 1971; and Plourde 1975) have stressed the fact that stocks of species and habitats are in themselves arguments in individual utility functions and should be accounted for in the NED or other accounts despite the fact that their values are not revealed in market-determined prices. This dichotomy in valuing between the stock and the flow has been recognized by economists as a general phenomenon for most publicly owned resources whose stock values have been normally assumed to be either zero or insignificant to individual consumers. Only until recently Miller and Menz (1979) and Thomas, Liu, and Randall (1979) have attempted to provide a welfare model for analyzing both the stock and the flow values for specific wildlife habitats and wetlands.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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The primary objective of this paper is to seek alternative means by which the cross-impacts between stock and flow valuation of fish and wildlife habitats may be explored and assessed so that both types of values--the nonrenewable resources and the consumptive uses--can be better defined and more reliably presented in the pertinent accounts.

A MODEL FOR FISH AND WILDLIFE HABITAT EVALUATION

Economists since Adam Smith had long been troubled by the paradox of value; i.e., how is value determined? Why do water and air, which are essential to life, have little or no value while diamonds have a very high market value? From Smith to Marx, most economists believed the labor-value concept, stating that it is the amount of labor that went into the production of a good or service that determined its value. Later, economists such as Jevons and Marshall developed the theory of marginal utility to explain the paradox of value, allowing that the utility of anything is entirely subjective. Marginal utility refers to the satisfaction derived from the consumption of any additional unit of goods or services. The two fundamental propositions underlying the marginal utility theory are that all rational individuals attempt to maximize their total utilities subject to their capability constraints and that marginal utility will diminish after a certain level of total satisfaction is reached.

Fish and wildlife habitats, whether terrestrial, aquatic, inland wetland, or coastal wetland and estuarine, should be valued as a capital resource, the stock of which can be transformed, directly or indirectly, into some positive physical attributes. These attributes, in turn, become either final outputs or factor inputs for the production of a flow of output (or goods and services) over time, and the flows are utilized, directly or indirectly, in satisfying human needs and wants. The kinds, quantity, and intertemporal patterns of the flow of goods and services transformed and produced from the habitats depend upon the complex interaction of man's resource allocation decisions with biological, geological, hydrological, and ecological conditions over which man has little influence. When habitat considerations became important in the evaluation of alternative projects and programs under the 1973 "Principles and Standards" established by the Water Resource Council, decisionmakers were most often faced with the evaluation of adverse impacts on the productive capacity of the habitats.

With the exception of calculations of economic losses due to reduced recreational fishing and hunting of game species, the Principles and Standards address the loss of habitat services solely in the context of the EQ account. Economic valuations of the loss of other habitat resources and their associated goods and services essentially have been missing from project evaluation, let alone the stock values themselves. Normally, the demand for the stock of habitats is a derived demand, and the physical attributes of the habitat area are consumed indirectly as a result of complex interactions between environmental vectors, e.g., basin stream flows, and human wants, e.g., flood damage reduction. In addition, almost all goods and services (output) produced by habitat, the flows, are delivered and consumed in an extramarket fashion and frequently valued at either zero or nominal price. Furthermore, the social opportunity costs of these capital resources have hardly been addressed.

The proposed model for valuing fish and wildlife habitats is a neoclassical partial equilibrium model in which the value of goods and services is determined in a similar manner with the supply and demand cleared in the market at the equilibrium price level and all individuals rational consumers. They always attempt to maximize their utility or satisfaction subject to their budget and income constraints over time. The intertemporal utility function for individuals of certain preferences for certain habitat stocks (S) and the flows of goods and services using fish and wildlife species as an input (Q) may be expressed as follows.[1]

$$U_i = U\left[Q_{i1} \cdots Q_{it};\ T(S_1 \cdots S_t);\ X_{i1} \cdots X_{it}\right] \tag{1}$$

where X is the amount of other goods and services consumed by the individual i in time period t.

The transformation function of habitats and their associated attributes $T(S_t)$ depends on the natural characteristics of the stock resources and the rates of growth (G) and harvest (H) of species under consideration:

$$T(S_t) = T\left[G(S_{t-1}) - H_t\right] \tag{2}$$

And the production relationships for Q and X are the following with R the amount of composite resource inputs used to produce both Q and X:

$$\begin{aligned} Q_t &= Q(H_t, R^g_t) \\ X_t &= X(R^z_t) \end{aligned} \tag{3}$$

The conditions for optimal intertemporal resources allocation are obtained by maximizing a social welfare function encompassing individuals in the present and future generations within a finite planning horizon. Following Baumol and Oates (1975), Page (1977), Smith (1968, 1977), and Miller and Menzi (1979), the social welfare function to be maximized is

$$V = V(U_1 \cdots U_n) \tag{4}$$

subject to the following constraints:

$$\begin{aligned} &\Sigma_i Q_{it} \le Q_t \\ &\Sigma_i X_{it} \le X_t \\ &R^g_t + R^x_t \le R_t \quad \text{or} \\ &(Y^g_{it} + Y^x_{it} \le Y_{it} \text{ for individual's income}) \\ &T\left[G(S_{t-1}) - H_t\right] = T(S_t) \quad \text{or} \\ &G(S_{t-1}) = S_t + H_t \text{ for species stock} \end{aligned} \tag{5}$$

To maximize the social welfare, we form a Lagrange maximization equation with appropriate multipliers (α, β, γ, θ, $\varnothing$, and τ) and solve the equation for the necessary conditions by taking the partial derivative with respect to each individual variable and setting it to zero:

$$\begin{aligned} L = V(U_1 \cdots U_n) &- \Sigma\alpha_t (Q_t - \Sigma_i Q_{it}) - \Sigma\beta_t (X_t - \\ &\Sigma_i X_{it}) \\ &- \Sigma\gamma_t\ (R_t - R^q_t - R^x_t) - \\ &\Sigma\theta_t\ (S_t - G(S_{t-1}) + H_t) \\ &- \Sigma\varnothing_t\ (Q_t - Q(H_t, R^q_t)) - \\ &\Sigma\tau_t\ (X_t - X(R^x_t)) \end{aligned} \tag{6}$$

The procedures above highlight many criteria for efficient resource allocation in an economy where both the stock (the existence value plus the size and other physical characteristics of the habitat attributes) and the flow of goods and services produced from the attributes of the fish and wildlife habitat in conjunction with other resources are considered. For individuals who consume non-negative amounts of Q, S, and X in any time period t, the necessary conditions for utility maximization are that the marginal rate of substitution (MRS) between goods Z, S, and X in time t must equal their respective marginal rates of transformation (MRT); and in turn, these ratios must be equal to the respective ratios of the marginal resource costs of Q, S, and X. For any individual i, the MRS of the non-fish and wildlife related goods X between time periods t and t + 1 must equal its price ratio in utility units and the ratio of its marginal costs between time periods t and t + 1. For any two individuals, the weighted marginal utilities of Q or S must equal the ratio of marginal resource costs between the two periods.

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[1] The habitat stocks are general terms; they refer to the overall capital resources including the entire ecosystem and the population stocks of fish and wildlife species.

Let us consider the supply of habitat goods or services Q_i $(i = 1, \ldots, n)$. Physically, habitats possess directly or can provide indirectly a vector of attributes (A_t). The production functions for habitat attributes are ecological input-output relationships uniquely determined by biological, geological, hydrological, and meteorological relationships, among others. These have been referred to as the physical production functions which transform the habitat into habitat attributes and hence into productive factor inputs such as the stock of species to be harvested (H_t).

In other words, man enters the system for production or consumption purposes as a modifier of the habitat and its attributes with other resources and effort (E):

$$\begin{aligned} H_t &= h(A_t(S_t),\ E_t^q) \quad \text{or} \\ Q_t &= [h(A_t(S_t),\ E_t^q),\ R_t^q] \end{aligned} \qquad (7)$$

Recognizing the transformation and production relationship between S and Q through H, there exists obviously an externality-type relationship between the stock and flow variables and hence the cross-impact between Q and S. In addition to their independent values, there are also synergistic values between the two. For us, then, fish and wildlife habitats have three types of value: the existence and the uniqueness at a particular point in time (S), the goods and services produced from the habitat per unit of time (Q), and the resulting interaction between S and Q over time through natural system changes and man-made improvements. As a result, the demand for the stock and the flow of goods and services which were produced by habitat attributes for satisfying human wants, or utility maximization, may be expressed as a function of the opportunity cost or the willingness to pay (WTP) and the cost of the service supplied (cost):

$$\begin{aligned} S_t &= f(\mathrm{WTP}_t),\ \partial Q/\partial f < o,\ \partial^2 Q/\partial f^2 \geq,\ o \quad \text{or} \\ Q_t &= f(\mathrm{COST}_t),\ \partial Q/\partial f > o,\ \partial^2 Q/\partial f^2 \gtrless o \end{aligned} \qquad (8)$$

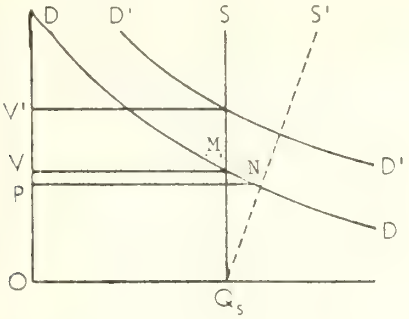
It is fairly clear from Equations (1) through (8) that we have illustrated a model for valuing habitat stock and habitat goods and services from the individual factor input demand and marginal utility framework. Specifically, we suggest that all human beings are rational and they all attempt to maximize their utility, subject to taste, time and income constraints. To maximize their utility, they demand habitat attributes, either transformed or untransformed, and goods and services which are produced by the habitat either directly or indirectly. The value of these stocks and flow of goods and services are reflected in the demand functions either in terms of an individual's willingness to pay or the costs of obtaining the goods and services. The demand curve for the goods and services is negatively sloped with respect to WTP or cost if they are normal goods and services and if the marginal utility derived from each additional unit diminishes after a certain level of total consumption is reached, while other factor inputs are held constant.

The general conceptual model for valuation of habitat may be summarized as follows:

Habitats are capital resources whose value can be evaluated from: (a) stock characteristics of the existence, uniqueness and/or nonrenewability of the habitat itself, (b) flow characteristics of the input factors that the habitat directly and indirectly provided for the production and consumption of goods and services, and (c) the synergistic characteristics of (a) and (b) alternated under varying natural and human forces over time. Habitats and goods and services produced from the habitat attributes are demanded by utility-maximizing individuals intratemporally and intertemporally and are thus valued differently among individuals according to their marginal utility and cost comparisons, and marginal rate of substitution and transformation calculations.

VALUE ASSESSMENT OF THE HABITATS

The habitats have been considered as capital resources. Since they are primarily publicly owned capital resources and there are complicated problems such as non-marketability, indivisibility, externality and social welfare indeterminancy and uncertainty involved in pricing the stocks and flows of the resources from the seller's reservation price (i.e., the minimum price that the owner of the resources is willing to sell), the last section suggests a demand model in assessing the values of the habitat. Employing a demand model for evaluation has been the most popular and scientifically acceptable approach for empirically estimating the economic value of goods and services which are fixed in supply at any time. Under the fixed supply assumption, the demand curve, which resembles the marginal utility of the individual, determines the value of the goods or services, as shown below:



The demand curve, DD, shows the maximum willingness to pay for the service at a fixed supply of OQs. The maximum value or willingness to pay is then OV, and the consumer's surplus is hence DVM. Given a resource alteration that increases the demand by shifting it from DD to D'D', the value of the fixed service becomes OV' per unit.

If the supply of the service is not fixed and the attributes of habitat can be physically increased (or decreased) through resource management decisions or other natural system alteration, the supply of goods and services is represented by positively sloped $S'Q_S$. Under this condition, the equilibrium price OP will be employed to derive the value of the service being studied. Thus, OP is a market price jointly determined by the seller and the demander. Market prices are the prices at which trade takes place, in this case trade which results in the diversion of resources from their present uses to the proposed use. Trade takes place between a willing demander and a willing seller if and only if the demander's willingness to pay is equal to or greater than the seller's willingness to accept, i.e., the resource's social opportunity cost in this case. The resources simply will not be diverted from other uses to the proposed use in a competitive market or competitive market-like context unless the seller's opportunity cost or reservation price is met or exceeded by the buyer's WTP at the margin. The corresponding consumer's surplus is thus represented by the area DPN under the old demand curve.

The economic valuing concept stressed previously is the marginal utility theory, which considers only that the maximum willingness to pay may over- (or under-) estimate the value of the habitat goods and services by VP (OV minus OP) depending on whether or not the resource supply is fixed. Similarly, the difference may also result from the externality or the synergistic impact between resource stock and resource flow interactions. This problem may be avoided if the social opportunity costs of habitat attributes and services are predetermined. However, empirically this is not the case. Most economic valuing methods are generally confined to the demand-oriented concept of valuation for fixed supply of habitat attributes, let alone the value assessment on depleting habitat stocks and the cross-impacts of the stock-flow transformations and interactions.

As pointed out by Dwyer, Kelly and Bowes (1977) and Thomas, Liu and Randall (1979), among others, there are more than a dozen quantitative approaches available for valuing habitat attributes and services through the measure of the consumer's surplus. Generally the methods are classified under the market observation technique and the contingent valuation technique. Although each of them has its own weakness and strength both conceptually and practically, the statistical inferential methods, particularly the travel-cost methods, have been perceived as a preferable technique over many others and have been employed most frequently in the empirical applications for assessing the consumer's surplus, or for approximating the true willingness to pay. Hotelling (1949) pioneered the travel-cost method for evaluating a recreational resource, and further refinements were provided by Cicchetti, Fisher and Smith (1976), Clawson and Knetsch (1966), Davis (1964), Gum and Martin (1975), Hammack and Brown (1974), Liu and Christiansen (1979), among others, for measuring the recreation demand and/or the consumer's surplus. However, the demand for habitats may by simplified and reduced from a simultaneous-equations system of models to as follows:

$$Q_t = f(TC_t;\ OC_t;\ TCOC_t;\ S_t;\ M_t) \qquad (9)$$

where TC is the round-trip travel cost, and OC is the opportunity cost of the recreationist including the time duration of visit and the potential earnings foregone; S_t is the stock attributes or capacity.

CONCLUDING REMARKS

Basically there are three classes of potential economic outputs from fish and wildlife habitats which policymakers are required to address: traditional outputs, which are recognized as NED objectives. Their values are quantitatively assessed (e.g., recreation, commercial fisheries); nontraditional outputs, which are recognized as NED objectives but their values are seldom estimated (e.g., land stabilization, erosion control); and nontraditional outputs which have, as yet, no counterpart in NED valuations (e.g., seasonal habitat for migratory, nongame species; depletion of the unique capital resources, etc.). To complicate the situation, the selection of evaluation techniques to place economic values on all these classes of habitat stock and flows of goods and services is, in some respects, the least of the problems facing policymakers. Much less understood than the alternative valuation techniques are the physical production and transformation functions by which the flow of goods and services occur under varying ecological and socioeconomic conditions. Still another aspect of the problem is the question of how resource management alternatives could be used to maximize these outputs once they are identified and their ecological conditions understood.

This paper suggests that not only the "flow" values of habitats be measured but also that the "stock" values be evaluated and the "cross-impacts" or the interactions between the stock and flow variables be recognized and considered over time so that the overall social welfare aspects of the habitats can be better comprehended for purposes of preservation and conservation. The conceptual framework and the empirical technique for valuing these habitats have also been delineated, however tentative they may look. Further refinement in these areas is certainly worth exploring.

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The Role of Mitigation in Water-Resource Development Projects That Benefit Wildlife: An Empirical Study of On-Farm Pheasant Mitigation Potentials in the Columbia Basin[1]

Scott C. Matulich[2]

The applicability of mitigation to water-resource development projects that benefit wildlife is investigated. An empirical model is then developed to assess the economic feasibility, extent and policy implications of such mitigation. While legal impetus to mitigate loss of planned benefits exists, mitigation must be carefully conceived to be economically feasible.

INTRODUCTION

The charge of this symposium is to bring together relevant issues that bear upon the mitigation concept and guide policy makers towards a uniform set of mitigation policies, procedures and goals. In concert with this objective, I will address one aspect of mitigation previously omitted from the purview of policy makers, but which is of compelling policy importance. The essence of this paper can be framed by a single question: To what extent does mitigation bear upon projects which benefit wildlife from the creation of new habitats? An immediate response is most likely "none". Mitigation is commonly and widely interpreted as alleviation of adverse impacts upon wildlife, pursuant to the Fish and Wildlife Coordination Act. Applicability is limited to those federal water projects which a) were authorized subsequent to the enactment of that Act, and b) have less than 60 percent of the estimated construction costs obligated (section 662-g). It would seem then, that subject to these limitations, costs in terms of foregone wildlife benefits resultant from project development must be mitigated. That is, only decreases from the pre-project base population levels must be ameliorated. But this concept of mitigation is myopic and moreover, is in direct conflict with the Act.

The Fish and Wildlife Coordination Act requires that any report prepared for the authorization, modification or supplementation of water-resource development projects include as a integral part, recommendations

> "... for the purpose of determining the possible damage to wildlife resources and for the purpose of determining means and measures that should be adopted to prevent the loss of or damage to such wildlife resources, as well as to provide concurrently for the development and improvement of such resources ... The reporting officers in project reports of the federal agencies shall give full consideration to the report and recommendation of the secretary of the interior and to any report of the state agency on the wildlife aspects of such projects, and the project plan shall include such justifiable means and measures for wildlife purposes as the reporting agency finds should be adopted to obtain maximum overall project benefits [emphasis added]." (Section 662-b.).

> "In addition to other requirements, there shall be included in any report submitted to Congress supporting a recommendation for authorization of any new project for the control or use of water as described herein (including any new division of such project of new supplemental works on such project) an estimation of the wildlife benefits or losses to be derived therefrom including benefits to be derived from measures recommended specifically for the development and improvement of wildlife benefits (including the cost of additional

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[1] Paper presented at The Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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> facilities to be installed or lands to be acquired specifically for that particular phase of wildlife conservation relating to the development and improvement of wildlife), the part of the cost of joint-use facilities allocated to wildlife, and the part of such costs, if any, to be reimbursed by non-Federal interests [emphasis added]." (Section 662-f.)

Clearly, both wildlife costs (in terms of direct losses) and benefits (in terms of planned or expected net gains) must be incorporated into the project feasibility analysis. This requirement calls for broader application of the traditional mitigation concept; mitigation refers to not only alleviating impacts adverse to the pre-project base population, but also to alleviating loss of benefits which were planned and/or programmed into project feasibility.

The above distinction is not moot. In fact, it imparts an important policy impact upon federal water-resource project analysis. Apart from the legal requirements, this broader interpretation is consistent with economic rationality. If project feasibility is at least partially conditional upon expected benefits to wildlife, then failure to maintain at least this programmed level of benefits may violate project feasibility. One must then question the expenditure of public monies on the entire project.

The practical significance of this problem becomes apparent when cast in the setting of irrigated agriculture. A two-phased senario commonly accompanies irrigation development. Creation of new habitats accompanies early irrigation development which in turn sponsors a rapid rise in wildlife populations. However, project maturity typically brings more intensive land use patterns, and technological and structural changes which promote cropping efficiencies with little or no regard for wildlife. Advances in irrigation technology and increased mechanization, for example, have led to the adoption of clean farming practices, drainage of wet lands, crop specialization, removal of fence rows and a host of other factors that have contributed to habitat destruction or loss of habitat diversification. The transformation of irrigated agriculture into a capital intensive industry has left wildlife vulnerable since they compete for high valued irrigated cropland (National Academy of Sciences, 1971; Goldstein, 1971). Thus, if wildlife benefits are programmed into project development in accordance with the Fish and Wildlife Coordination Act, the likelihood of mitigation is almost certain.

Mitigating losses of planned wildlife benefits is not without profound impact upon management agencies charged with the responsibility to implement mitigation. The Fish and Wildlife Coordination Act specifies that the appropriate federal construction agencies must provide all capital costs required for mitigation. However, the financial burden of operation and maintenance costs are relegated to either the U.S. Fish and Wildlife Service or state Game Departments (section 662-b and 663-b, c). Questions regarding the economic feasibility and extent of mitigation should be a fundamental concern to these agencies, given limited operations monies. Despite the legal mandate to mitigate fish and wildlife losses, efficient use of public monies should surface as critical management objectives. There may be cases where mitigation should not be pursued under the institutional realities of the Fish and Wildlife Coordination Act.

The remainder of this paper presents a framework to assess both the feasibility and extent of mitigation. An empirical study of the Columbia Basin Irrigation Project provides the basis for analysis.[3] This problem setting serves as a pedagogical device in that fish and wildlife benefits were not planned into the project at the time of its conception. Nonetheless, the analysis procedes under the supposition that benefits were planned at the level of maximum pheasant harvests. Washington Department of Game activities and proposals are discussed here as mitigation (for expository purposes).

BACKGROUND

The United States Bureau of Reclamation developed a project to irrigate over one million acres of desert in Washington's Columbia Basin. Project waters were first delivered in 1952. As irrigation expanded, pheasant populations flourished until the mid-1960's; pre-project bird harvests increased from 10,000 pheasant to more than 250,000 pheasant. A dramatic trend reversal accompanied subsequent project maturity. By 1977, pheasant harvests had declined 50 percent from their previous high. Recreational benefits decreased accordingly.

Recognizing that the transformation of agriculture was the primary cause of pheasant losses, the Washington Department of Game began searching for on-farm means of stabilizing and increasing pheasant populations. Numerous methods were identified to re-establish and maintain permanent habitat, and to alter farming practices that are incompatible with pheasant productivity. However, attempts to impose these practices on Columbia Basin farmers were rebuffed.

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[3] See Wolfley et. al. for a detailed discussion of this research.

The farming community viewed the recommended tices as costly nuisances that would restrict crop production and drastically erode profits.

Throughout the development process, farmers strived to achieve cropping efficiencies that maximize net farm returns. These efficiency gains are now the source of controversy between farmers, wildlife managers and the general public. Farmers are unwilling to relinquish these gains and bear the cost of mitigation. They argue pheasant production must remain incidental to the cropping process. Their position is supported by a recent OWRT report which states "... irrigated land will be almost impossible to manage for the benefit of wildlife. Any beneficial relationship between irrigation and wildlife on cultivated land will be incidental." (Peterka, 1975, p. 42.)

The conflict between irrigated agriculture and the public mandate to mitigate pheasant losses has polarized the various interest groups. In the absence of apparent legal obligations which bind existing irrigators to deliberately allocate resources toward wildlife production, provision of economic incentives are necessary to change the status of wildlife to an intentional production alternative. The amount and type of resources farmers will voluntarily divert from cropping activities depends upon the level of economic incentives for wildlife production relative to other production possibilities. That is, compensation required to shift resources to wildlife production must equal or exceed the opportunity cost (foregone income) from crop production. Without adequate incentives, the future for wildlife in irrigated agriculture is not bright. Wildlife benefits will continue to be incidental to cropping; as opportunities to increase farming efficiencies continue to arise, further conflicts between crop and wildlife production can be expected.

ANALYTICAL FRAMEWORK

The economic impact of alternative on-farm mitigation practices was analyzed using the Oklahoma State University Budget Generator. (Kletke, 1975) Typical farm practices were modeled into enterprise budgets for two farm sizes, three irrigation systems and five crops in six rotations.[4] These base budgets were then modified to incorporate nine pheasant mitigation practices which were selected by an advisory committee comprised of Game Department personnel, farmers and irrigation district managers. Establishment of undisturbed perennial cover, variations of first-cutting alfalfa harvest methods and provision of winter food were modeled. Differences in net revenue between base and modified enterprise budgets were considered measures of the opportunity cost associated with implementing the various enhancement practices. Opportunity costs for each enterprise were then aggregated, by rotation, to provide an estimate of farm level opportunity costs. Relating farm level pheasant response estimates with foregone farm income provides a measure of opportunity costs per additional bird.

The feasibility of selected mitigation practices was established using a two-fold criterion. The cost of producing pen-raised birds provided a cost estimate of an alternative production process. Current Game Department costs of raising and releasing pheasant total $6.14 per bird. Additionally, a direct measure of net benefits received from the consumptive value of pheasant was employed. Wolfley developed marginal value estimates for Columbia Basin pheasant based upon the direct survey method of measuring willingness to pay as adapted by Hammack and Brown (1974). The estimated mean marginal value over the entire sample population was $5.83 per bird, but ranged from $.57 to more than $39.00. This mean marginal value in concert with the Game Department cost of producing pen-raised birds establish the two feasibility criterion. Mitigation practices exhibiting small opportunity cost deviations above these value estimates may be potentially feasible. Habitat improvement provides additional unmeasured benefits corresponding to superior survival abilities and greater hunting value of wild pheasant, in addition to extensive unmeasured benefits accruing to other consumptive and nonconsumptive wildlife.

EMPIRICAL RESULTS

Foregone farm income, pheasant responses, and opportunity cost per bird are presented in Table 1 according to enhancement practices, farm size and rotation. Variations among irrigation

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[4] The five crops considered (alfalfa, grain corn, wheat, potatoes and sugar beets) account for 75 percent of the cropped acreage in the Basin. The two farm sizes considered (160 and 320 acres) are commonly found in the Columbia Basin. Farms containing 320 acres or less, represent over 80 percent of operational farms and 56 percent of the irrigated acreage in the project. Gravity flow and sprinkler irrigation systems were modeled even though the project was designed for gravity irrigation. The advant of the sprinkler technologies combined with varied topography and soil characteristics throughout the Basin, promoted adoption of side roll and center pivot systems in addition to rill irrigation.

Table 2. Foregone Farm Income, Expected Mean Pheasant Responses, and Opportunity Cost per Pheasant for Alternative Enhancement Practices: By Farm Size and Rotation (1973-1977 prices)

		160 Acres			320 Acres		
Enhancement Practices	Rotation[a]	Foregone Farm Income	Pheasant Response	Opportunity Cost per Pheasant	Foregone Farm Income	Pheasant Response	Opportunity Cost Per Pheasant
		(dollars)		(dollars)	(dollars)		(dollars)
Cover Crops[b]							
Strips [c]	A	110-172	16-20	6.88-8.74	313-442	32-39	9.80-11.41
	W-P	320-414	16-20	17.07-21.02	668-838	32-39	17.44-21.42
	W-P-W-SB	258-332	16-20	14.60-16.87	526-673	32-39	16.45-17.09
	W-W-W-SB	156-215	16-20	9.76-10.91	323-444	32-39	10.10-11.28
Corners[d]	A	6,237-6,550	83	72-81	15,396-16,801	166	93-101
	W-P	16,327	83	196	33,134	166	199
	W-P-W-SB	13,094	83	157	26,729	166	161
	W-W-W-SB	7,909	83	95	15,712	166	94
First Cutting Alfalfa Harvest Variation							
Delay Mowing 1 Week	A	2,925-4,110	19-27	152	5,850-8,220	39-54	152
Delay Mowing 3 Weeks	A	7,924-11,135	85-120	93	15,943-22,761	171-240	93-95
Raise Mowbar 10 Inches	A	7,244-10,179	85-120	85	14,489-20,358	171-240	85
Winter Food Supply							
Corn Stubble	A	850-1,046	1.3-1.6	654	1,698-2,090	2.6-3.2	653
Unharvested Perimeter Corn Strip (10')	A	1,092-1,364	1.4-1.7	800	2,047-2,596	2.8-3.4	755

[a] Rotations are defined by the following notation: W=winter wheat; P=potatoes; SB=sugar beets; A=predominantly alfalfa rotations including A-W, A-W-W, and A-C-W (where C refers to grain corn). All crops are annual except alfalfa, which is assumed to have a 6-year perennial life.

[b] Both asparagus and alfalfa/big blue grass/fescue mixture are included as cover crops for strips and corners.

[c] Two six-foot wide strips were planted the length of opposite farm edges.

[d] Four 7.5 acre corners were planted to perennial cover crops for each 130-acre center pivot irrigation system.

systems were slight and are therefore, aggregated in this table. Similarly, operations dominated by the alfalfa enterprise are combined together, including alfalfa-wheat, alfalfa-corn-wheat and alfalfa-wheat-wheat rotations.

Opportunity costs range from $6.88 to $800.00 per bird. This wide range reflects the relative pheasant response rates as well as the value of crops in generating farm income.[5] Cover crops in the form of strips were found to offer potentially feasible enhancement methods. Strips in association with low value crops yield costs of $6.88-$8.74 per pheasant for the 160 acre farm. In light of additional unmeasured benefits to other wildlife attending habitat development, these costs compare favorably with that of pen-raised pheasant and the estimated mean marginal value of pheasant.

Costs of $10-$21 per bird were estimated for 320 acre farms. Strips in high value crop rotations, i.e., potatoes and sugar beets, also yield a cost per bird of $10-$21 irrespective of farm size. The alternative use value for land planted to high value crops (potatoes and sugar beets) is always greater than land planted to lower valued crops (alfalfa, corn and wheat). Since modification of farm operations for the benefit of wildlife is the same for all crop types considered, the higher valued crops are associated with higher opportunity costs. Both corner cover crops and alfalfa harvest variations are associated with much higher opportunity costs, averaging $120 per bird. Provision of winter food supplies were found to yield extremely high costs of more than $600 per bird.

These results bring to focus an important wildlife management principle; the greatest marginal contribution to a wildlife population need not equate with the least cost mitigation practice. For example, planting corners to a cover crop generates higher costs per bird than strips in spite of the four-fold greater bird response associated with corners. Loss of harvestable cropland relative to farm level bird response is smaller for strips.[6]

Alfalfa harvest variations also proved uneconomical despite large bird responses. Raising the mowbar an additional ten inches was least expensive followed by delaying the first cutting three weeks and one week ($85, $94 and $150 per bird, respectively).

Supplying winter food is an example of what outwardly appears to have little impact on farm income, but in fact has a large unforeseen opportunity cost. Stubbling, for example, seems to have no economic impact other than altering seasonal workloads. However, there is a hidden cost from not being able to follow with the most desired rotation crop. Both winter food supply practices require following corn with spring wheat as opposed to winter wheat--reducing wheat yields 20 bushels per acre.

Farm size was found to impact the opportunity cost per bird in nearly every mitigation practice. In particular, the 160 acre farm size exhibited lower opportunity costs than the 320 acre farm. This conclusion is a consequence of economies of size. Two exceptions are noted. Planting corner cover crops in the three year wheat-one year sugar beet rotation faced slightly higher opportunity cost per bird on the 160 acre farm. The additional economies gained from farming corners on 320 acres are less than those on 160 acres. Supplying winter food by leaving an unharvested perimeter corn strip also incurred lower opportunity costs on the 320 acre farm. A greater percentage of the smaller corn field is left unharvested than with the larger field. This difference in unharvested acreage offsets any economies achieved with the larger farm.

CONCLUSIONS AND IMPLICATIONS

Irrigation development has failed to guarantee long-term production of wildlife benefits, even when such benefits are among project objectives. The zero priced, nonmarket characteristic of wildlife inhibits farmers from intentionally allocating resources to their production. As opportunities arise to increase cropping efficiencies, farmers can be expected to adopt practices even more inimical to wildlife. Mitigation may be necessary to assure realization of long-term wildlife benefits. But mitigation, particularly on-farm mitigation, should be recognized as both costly and controversial. While there appears to be legal impetus to mitigate losses of planned benefits, care in selecting the means and methods of mitigation is critical. Arbitrary or capricious policies can force economic hardships upon irrigators and are certain to meet with opposition from the agricultural sector. Failure to recognize the underlying production interdependencies and economic tradeoffs between agriculture and wildlife is likely to contribute to the infeasibility of mitigation.

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[5] Relative response rate refers to the estimated number of birds generated by a particular enhancement practice.

[6] Corners consume 30 acres of the 160 acres and yield 83 birds farm-wide. By comparison, strips account for only 0.7 acres, yet enhance 20 birds. Stated equivalently, corners accomodate less than 3 birds per acre of cover crop as opposed to more than 27 birds per acre of cover in strips.

The rise and decline of Columbia Basin pheasant populations exemplifies the impact of irrigation development upon wildlife. The results of this analysis, in contrast with that found by Peterka (1975), suggest pheasant production need not be an unintentional by-product of agriculture. Costs of $6.88 to $8.74 per additional bird were found by providing strips of permanent cover on small farms growing less intensively farmed, low value crops. It is here that alternative resource useage exhibits the most favorable economic tradeoffs. By comparison with the $6.14 pen-raised bird cost and the estimated mean marginal value of $5.83, and in consideration of additional value corresponding to greater survival rate, hunting value of wild birds and extensive unmeasured benefits to other wildlife, mitigation of losses to planned wildlife benefits appears potentially feasibble. Feasibility may be futher promoted if least cost mitigation strategies are directed towards farms yielding high bird responses.

However, substative change in the present game laws is essential if mitigation is to be feasible. Hunting regulations must be liberalized in the mitigation areas to allow bagging of some hen pheasants. Opportunity costs per bird are predicated upon total increased bird resonses, but current hunting regulations stipulate bagging of roosters only. Failure to harvest hens would approximately double the cost of mitigation and threaten feasibility. Limited hen hunts, though a biologically sound management practice, are a sensitive political issue that must be resolved if mitigation is to be economically efficient.

It is doubtful that mitigation should be implemented to the extent of maintaining maximum wildlife benefits that might be derived from an irrigation project. This maximum benefit level should be regarded as a short-term windfall gain. It is coincident with temporary biological complementarities between irrigation development and wildlife. The distinction between long-term and short-term benefits is crucial to defining the extent of mitigation that can be sustained economically. The case of the Columbia Basin pheasant illustrates this point. Feasible mitigation is practicable to offset only 20-30 percent of the pheasant losses incurred.

This conclusion raises the horns of a dilema. On the one hand, conservative estimation of wildlife benefits will hold down the extent of mitigation required by the Fish and Wildlife Coordination Act. Estimation only of sustainable long-term benefits is consistent with assuring mitigation feasibility. But incentives exist concurrently to disregard future mitigation difficulties in favor of project feasibility at the time of project planning. Maximum short-term benefits contribute more to overall project feasibility. Resolution of this dilema is difficult, but necessary to assure uniform mitigation policies and procedures.

One would be remiss not to address funding of on-farm mitigation, especially in light of the potential financial burden it imposes on state or federal management agencies. Equity considerations suggest the cost of mitigation should be transferred to those who would benefit. The most obvious beneficiaries are hunters. Hunters, however, are not the only segment of society which would benefit from mitigation. A more detailed analysis of the beneficiaries may provide a broader base from which to select the most equitable method of deriving revenues to be used to compensate farmers for lost income.

Mention should also be made of the role of risk and uncertainty in securing farmer participation. Compensation requires contracts pledging participation, and contract life is a critical consideration in maintaining a stable pheasant population and avoiding transient wildlife benefits. But crop price and yield variability pose serious impediments to long-term contractual arrangements. Given an unwillingness to commit resources well into the future, it is unlikely that contracts longer than a few years could be secured. Management agencies should consider the contractual costs of on-farm mitigation in their initial program planning. A further contractual consideration involves transference of public monies to private property owners; public access to enhanced areas must be assured.

The specific findings of this study are conditional upon the following limitations.
1) No attempt was made to determine the optimum cover crop strip width--the least cost practice. An alternative stip width or configuration may achieve lower opportunity costs per pheasant.
2) Only two potential cover crop varieties were analyzed. Other grasses, various woody covers and commercially grown crops may alter mitigation costs.
3) Pheasant response estimates provided by the Washington Department of Game are preliminary. Refinement of these estimates, in addition to including variations among irrigation systems and cover crop varieties, could impact per bird opportunity costs and possibly alter the conclusions drawn in this analysis.
4) No attempt was made to model variations in crop quality of yield when grown under alternative irrigation systems. Data refinement may implicate irrigation systems as important

policy considerations.
5) Only costs in the form of direct income losses to crop production were analyzed. The increased cost, real or perceived, attending increased hunting pressure, possible crop depredation, vandalism and general nuisance has not been addressed. It is likely that these unmeasured costs must be reconciled to obtain contractual agreements. Monetary costs associated with these factors may be overcome in a number of ways. For example, the state could underwrite an insurance program to protect property owners from damage similar to that already established for disaster insurance. Costs of program implementation and enforcement have also been omitted from this analysis. Estimation of these costs would be necessary to assure feasibility. However, if mitigation is selectively applied to farms yielding high response rates, such costs are less likely to challenge feasibility.

The policy implications of this paper may be generalized, to a considerable extent, even though the analysis pertains to the Columbia Basin. Underlying problems and priciples are common to all irrigated agriculture, but the specific findings will vary according to the problem setting. Moreover, the concept of mitigation addressed in this paper can be applied to any water-resource project in which wildlife benefits were planned into project objectives. The implications are also valid for enhancement programs.

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Mitigation as Management: Strategy and Some Alternatives[1]

Larry S. Thompson[2]

Abstract.--Mitigation of impact, as well as the related concepts of impact prevention, compensation of impact, and trade-offs, may be considered to be types of population management. The optimum strategy should allocate available funds among these types of management, so that the greatest possible benefits to the resource can be achieved at the least cost. Cost-benefit analysis may be used to determine the relative cost-effectiveness of baseline study, impact analysis, mitigation, prevention, and compensation, and can be used to formulate the most cost-effective mix of management strategies.

INTRODUCTION

Mitigation of impact to fish and wildlife resources is assuming ever-increasing importance in project planning, especially as the rate of potentially damaging development increases. Discussion of mitigating measures and their effectiveness, however, which should be a major part of impact assessments, usually receives short shrift in most impact statements. Compensation and other alternatives to mitigation receive even less attention, since compensation requirements have been difficult to quantify, specific measures are hard to justify, and funding is difficult to extract. And cost-benefit analysis has scarcely been employed at all in determining the most beneficial use of available time and money. Mitigation is seldom thought of as a management tool, and its relation to the similar but distinct concepts of impact prevention, impact compensation, and trade-offs has not been clarified. In this paper, I hope to analyze the position of mitigation in the management spectrum, and to discuss why an optimum strategy for management should carefully weigh costs against benefits and optimally allocate effort among the different types of management -- of which mitigation is merely one.

THE MANAGEMENT SPECTRUM

Mitigation, as a management technique, occupies a position in a population management spectrum ranging from eradication at one extreme to enhancement at the other. Management is loosely defined here as any interference by man in the "natural" course of events; this definition encompasses both adverse and beneficial impacts, as well as intentional and unintentional interference. In the following discussion, the outcome of events with certain types of management will be contrasted with the probable outcome without such interference.

Figures 1 through 9 show, by means of very generalized graphs, nine major classes of population management. In all graphs, the abscissa represents local carrying capacity K, defined here as the optimum number of organisms which the local environment can sustain over a long period of time. Fortunately, a technique for assessing K has already been developed: the U. S. Fish and Wildlife Service Habitat Evaluation Procedures (HEP) (Schamberger and Farmer 1978). Using these methods, the ordinate would represent "habitat units" which are, in turn, proportional to K. Carrying capacity is commonly thought of as primarily a function of habitat, but it can also be strongly dependent on mortality and natality rates, local colonization rates, the competitive milieu, and various behavioral traits of the organisms. Thus, management serves to affect long-term numbers (carrying capacity) by adjustment of habitat characteristics, density of competitors, mortality rates, or by other types of interference with the "natural" trend. In figures 1-9, carrying capacity with management is shown by a dashed line; that which would be the case if the management technique were not applied is shown as a solid line.

An adverse impact to a population may be defined as any perturbation which (1) reduces K, (2) reduces population size temporarily below K, or (3) increases population size above K, the net effect of which is usually damage to habitat and eventual reduction in K. Similarly, a beneficial impact is any perturbation which

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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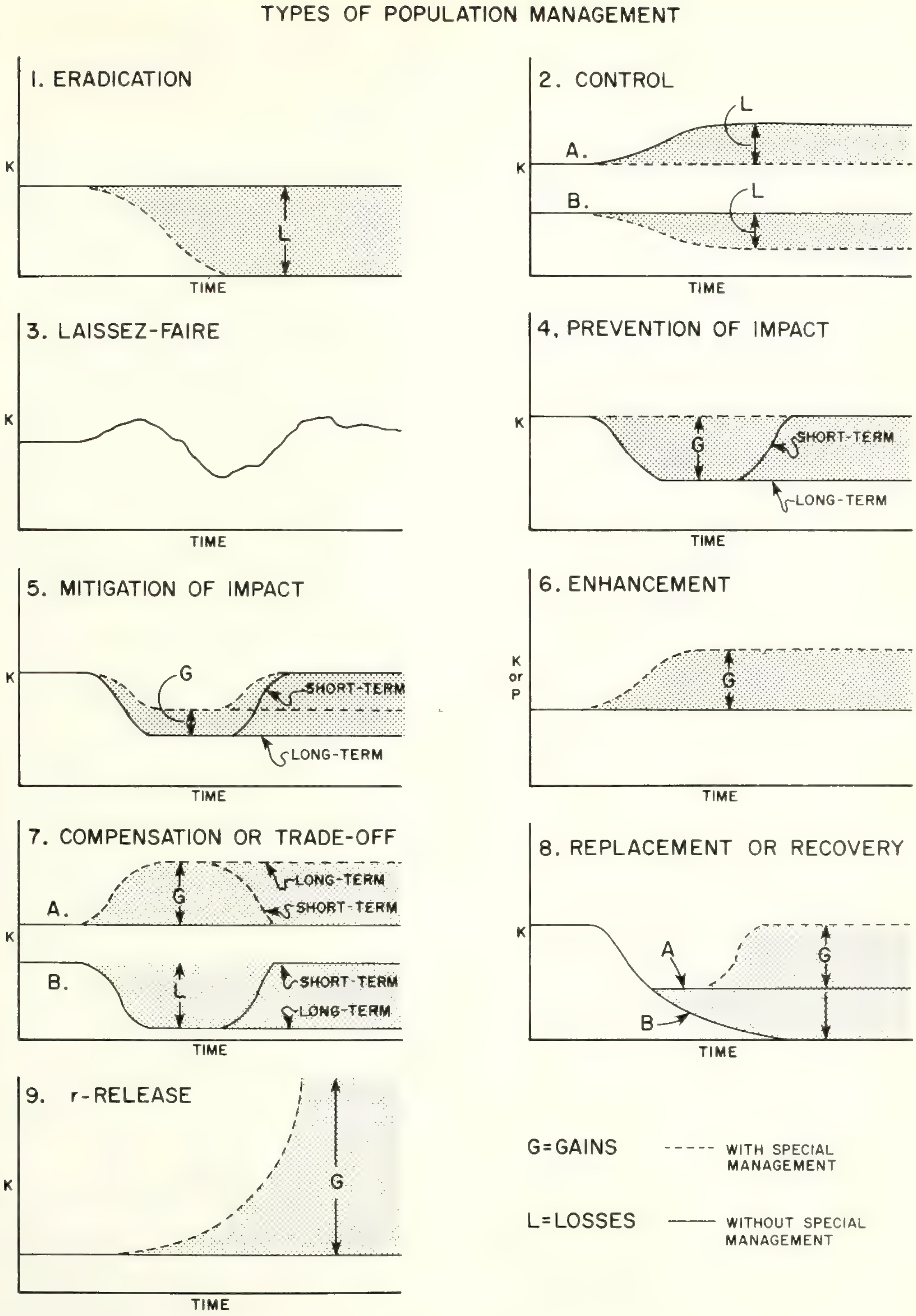

Figures 1-9.--Types of population management.

(1) restores depleted or oversized populations to K, or (2) increases K. Figures 1 and 2 show adverse impacts, while figures 4-9 portray beneficial impacts. Short-term and long-term impacts are shown separately in certain of these figures. For consistency, long-term impacts are defined as those impacts that affect many generations or age-classes of organisms, while short-term impacts are those which affect just a few. Thus, the time scale for a short-term impact may represent days in the case of bacteria or decades in the case of large vertebrates. Also, again to simplify presentation of general concepts, the carrying capacity curves have been smoothed out (in all but figure 3) by ignoring such fluctuations as seasonal and successional changes; more realistically, these graphs would resemble those shown by Christensen et al. (1975). Gains (G) and losses (L) are also indicated in the figures as shaded areas. The nine basic types of population management are discussed below.

Eradication.--(Fig. 1). This is management to eliminate populations of a species, that is, to drive the species to local or even global extinction. Eradication may be considered an extreme case of adverse impact, in which the population is completely destroyed.

Control.--(Fig. 2). The result of this type of management can be either the prevention of an outbreak or irruption of the population (A in fig. 2) or a reduction in K without bringing about total eradication (B in fig. 2). In either case, the result of management is to reduce the long-term number of organisms.

Laissez-Faire.--(Fig. 3). This is the type of management--or rather non-management--applied to most populations of most species of the world, particularly nongame species. Populations are simply left alone to fend for themselves, and K is left to change according to the vagaries of the environment. Nevertheless, there may be important costs associated with this type of management, as discussed later. Baseline study and impact analysis, for example, involve considerable expense to describe existing conditions or probable future conditions while attempting not to change the population or K at all. Also, the goal of much current nongame management is to simply maintain the status quo.

Prevention of Impact.--(Fig. 4). Prevention of impact also aims to maintain the status quo, but this is accomplished by taking measures to completely prevent the occurrence of an impact (as described above) which would otherwise occur. The impact prevented, and hence the gains or benefits that would accrue by impact prevention (shown by shading in the figure), may be short-term or long-term.

Mitigation of Impact.--(Fig. 5). Mitigation is management to reduce, abate, or alleviate an adverse impact. As such, it differs from prevention--the 100% reduction of potential losses--in that it is acknowledged that some loss will occur; the goal of management is to make that loss less severe. Thus, the gains or benefits to be realized from mitigation (shaded area in fig. 5) are somewhat less than those of full prevention. The situation with short-term mitigation is contrasted with mitigation of long-term impact in figure 5.

Three major types of mitigation management are commonly employed; these can be referred to as spatial, temporal, and operational mitigation. Spatial mitigation is the avoidance of areas with a high risk of adverse impact--for example, nest sites, winter ranges, or critical habitat--and is a primary goal of siting studies and corridor analys s. Temporal mitigation involves adjusting the timing of project-related activities to reduce impact severity in areas of high risk which cannot be spatially avoided. To accomplish temporal mitigation, project-related disturbances can be restricted to seasons when impact risk is least (for example, fall construction in the vicinity of a bald eagle nest), or the amount of time spent in a sensitive area can be reduced (for example, by scheduling double work shifts). Operational mitigation involves the employment of techniques that could reduce impacts--for example, directional drilling of pipeline river crossings rather than river trenching.

Enhancement.--(Fig. 6). This type of management results in either an increase in K or (as in the case of some domestic species) an increase in biomass productivity P with constant long-term numbers. This has traditionally been the focus of most wildlife management, and the techniques for enhancement management have been well developed. The shaded area in figure 6 represents the long-term gains or benefits that could result from appropriate management; this is equivalent to the "management potential" of the HEP (Schamberger and Farmer 1978).

Compensation and Trade-offs.--(Fig. 7). Compensation and trade-offs, while quite different conceptually, can both be represented by figure 7. Compensation involves enhancement to produce gains in K in one area (A in fig. 7) to make up for impact-related losses in K in another area (B in fig. 7). Thus, unmitigated losses are accepted, and an attempt is made to recoup these losses through intensive enhancement elsewhere. Compensation may be in-kind (e.g., lost elk habitat is compensated by increased elk management) or out-of-kind (e.g., lost pheasant habitat is compensated by increased deer management). The latter approach creates considerable problems, as it involves asking such questions as "how much sandhill crane management is necessary to compensate for loss of the whooping crane?" As shown in figure 7, losses or gains may be either short-term or long-term. Trade-offs, in contrast, presume that wildlife losses must be accepted if we are to achieve benefits of other types. This is the idea that, for example, sage grouse habitat located over a coal seam must be sacrificed so that we may have the coal; the losses in grouse K (B in fig. 7) have been "traded off" for gains in energy availability (A in fig. 7, with the ordinate representing energy availability rather than K).

A variation on the theme of compensation is that unmitigated losses in one area (B in fig. 7) may be partly compensated by prevention of losses in another area (fig. 4). For example, loss of riparian habitat by impoundment of a river can be partly compensated if means are provided to prevent imminent impoundment of remaining stretches of the river. This type of management differs from full compensation in that a net loss in K results, although this loss is not as severe as it would otherwise have been. This approach is often applied as trade-off analysis in siting studies. For example, the only options for locating a powerline may be a park and a wetland; if the line is sited in the wetland, the impacts to waterfowl must be accepted while recreational impacts are prevented. Again, the net result of this type of trade-off is a loss from the previous condition.

Replacement or Recovery.--(Fig. 8). Replacement is a special case of enhancement, following an impact which caused a reduction in K. It involves managing an area (often through reclamation or restocking) to restore K to previous levels (A in fig. 8). Even if restoration is complete, the result is a net loss proportional to the time lag between the impact and full replacement. In the extreme case, the population without this type of management would decline to extinction (B in fig. 8), thereby foreclosing the option of future replacement.

r-Release.--(Fig. 9). This type of management involves the removal of all checks or restraints on population growth, so that the intrinsic rate of increase (r) achieves its full potential and the population increases exponentially and indefinitely. The only species to which this management technique is currently being applied is man.

COST-BENEFIT ANALYSIS AND MANAGEMENT STRATEGY

Our primary goal, as fish and wildlife managers, is allegedly to work toward the benefit of fish and wildlife populations. Since we are always limited by the time and money available to accomplish this goal, we should employ the most cost-effective mix of management techniques available in order to maximize benefits to the resource. All management techniques discussed above (excluding r-release) may be drawn upon in developing such a mix. The optimum management strategy should allocate the finite resources among these types of management to most effectively achieve the desired end product, while consuming the minimum time and money. The methods of cost-benefit analysis (Mishan 1976; Sassone and Schaffer 1978) can be employed toward this end, whereby costs of mitigation and other approaches can be carefully weighed against the benefits to be obtained in light of the overall significance of the potential impact (see Sharma et al. 1975 for a discussion of impact significance). Mitigation or impact prevention alone may require higher costs per unit of benefit than a mix of mitigation with several other strategies. In certain cases, for example, compensation of impact coupled with prevention in another area may yield greater and more cost-effective long-term benefits than mitigation alone. This will be illustrated by several specific examples in the following discussion.

Costs and Benefits of Mitigation, Compensation, and Prevention

In figure 10-A, a solid curve is shown which represents, as a function of time f(t), the change in K resulting from an unmitigated, short-term impact. The dashed curve in this same figure shows how mitigation might serve to lessen the reduction in K over time according to a different function of time, m(t). The benefits B_m to the population which could be obtained by mitigation (or, as an extreme case, impact prevention), represented as the shaded area in figure 10-A, would thus be

$$B_m = \int_o^t \left[m(t) - f(t)\right] dt.$$

If the costs of mitigation are C_m, the benefit per unit cost (expressed as habitat unit days or a similar measure) is simply $B_m/C_m = E_m$, which is a measure of the cost-effectiveness of the technique. Different mitigating measures would, of course, result in different E_m values, and complete prevention of impact would probably have a lower E_m value than mitigation.

Figures 10-B and 10-C show two alternatives to mitigation; in both cases, the impact curve f(t) is the same as in figure 10-A, but the impacts are not mitigated and simply accepted as they are. The impact-related losses L to the resource are thus equal to the difference between the situation if the impact did not occur (represented by a dotted line and the function h(t)) and f(t), or

$$L = \int_o^t \left[f(t) - h(t)\right] dt.$$

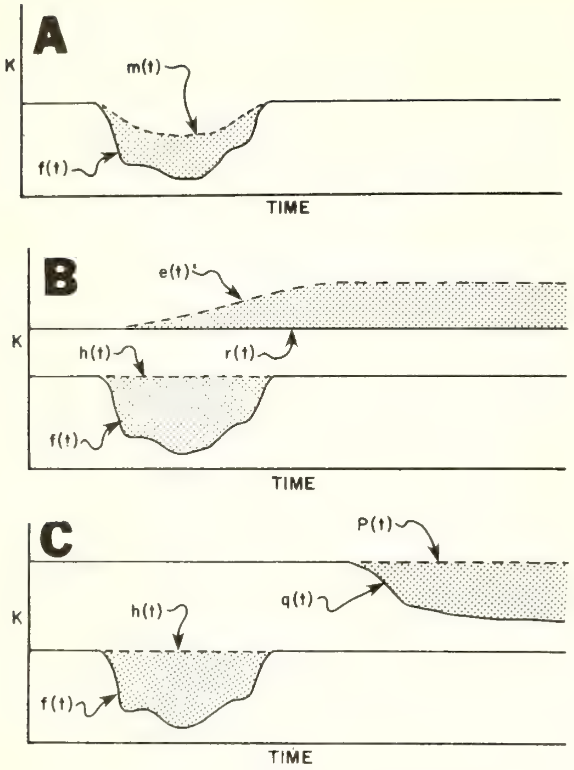

Figure 10.--Three possible strategies for dealing with a short-term impact.

In the case of compensation, the unmitigated short-term losses L could be made up for by enhancement in another area, the carrying capacity of which is represented by the solid line r(t) in figure 10-B. Long-term enhancement of this area may increase the incremental value of K only slightly each year (as shown by curve e(t)), but over many years the total gains of such enhancement

$$G_e = \int_0^t \left[e(t) - r(t)\right] dt,$$

properly discounted, may very well exceed the unmitigated losses L. It is clear that the longer enhancement can be applied, even if enhancement is very slight, the more substantial the long-term benefits that accrue over time. (NOTE: Unless discounted, any long-term compensation, however slight, would turn out to be the best strategy for dealing with a short-term impact.)

In this case, the overall net benefits of compensation B_c are equal to $G_e - L$. Assuming costs of enhancement equal C_e, the benefit per unit cost of compensation is $B_c/C_e = E_c$. This value can be contrasted to that of mitigation, E_m, to determine which strategy would be most cost-effective. A similar analysis could be applied to out-of-kind compensation or to tradeoffs between wildlife and another resource, but a weighting factor would have to be applied before any such comparisons could be made.

An example may serve to illustrate how compensation may yield greater overall benefits than mitigation. Assume that a major pipeline oil spill occurs during fall migration of birds through the prairie states, and results in the soaking of some 500 puddle ducks of different species with oil, which is highly publicized. The reflex reaction is to do everything possible to mitigate the losses by rehabilitating the oil-soaked birds. This would require a very expensive and labor-intensive sequence of events including capture of the birds, establishment and staffing of a rehabilitation center, treatment and feeding of individual birds, and extended care of the birds. Using standard procedure full rehabilitation of these birds would cost on the order of $12,000, not including costs of pick up, transport, pens, rent, and transportation of personnel. However, should winter arrive before the birds are released, and water areas freeze over, very few of the weakened birds would be likely to survive over the winter. In any event complete success or complete failure of rehabilitation would probably have no measurable effect on the number of birds arriving at the breeding grounds the following spring. Waterfowl populations are able to compensate for substantial hunting mortality (Anderson and Burnham 1976). While the harvestable surplus available to hunters may be reduced by the oil spill, K would probably show no effects at all. The costs of mitigation, therefore, are rewarded by few--if any--tangible benefits. On the other hand, if the oil-soaked ducks were allowed to die and the money were used instead for waterfowl nesting habitat improvement, wetland acquisition, or other enhancement measures, a tangible long-term benefit would accrue over time, exceeding any benefits which mitigation could provide.

Another strategy is to make up for unmitigated short-term losses L by impact prevention in another area. In figure 10-C, the solid line described by the function q(t) shows the change in K which would occur if nothing is done about the impact, and p(t) describes the situation if this impact is prevented. The total gains

$$G_p = \int_0^t \left[p(t) - q(t)\right] dt,$$

discounted over time, may in fact exceed the unmitigated losses L, in which case the overall net benefits are $B_p = G_p - L$. Assuming costs of prevention are C_p, the benefit per unit cost is $B_p/C_p = E_p$, which again may be compared to corresponding values for mitigation and compensation.

As an example, assume that a sagebrush area important to sage grouse is scheduled for mining. Mitigation of losses could be accomplished by preventing mining of that area, thereby denying public use of the coal resource, or by an expensive and labor-intensive replacement process that may not be completely effective. As an alternative to the restoration of the original vegetation at the reclaimed site, sagebrush-dominated rangelands in nearby areas also important to sage grouse could be afforded long-term protection via low-cost easements or dedications. This protection would not affect current use of the land--namely, livestock production--but would prohibit spraying or plowing of sagebrush, which destroy many acres of sagebrush habitat each year. The benefits of this acquisition may not be felt for decades but in some circumstances could result in a higher eventual value of K than would full reclamation, even if discounted over time.

Costs and Benefits of Inventory and Impact Analysis

The passage of NEPA and similar state legislation has mandated the consideration of fish and wildlife concerns in project planning, and has required evaluation of potential impacts which could affect these resources. Considerable sums of money have been made available to regulatory agencies to carry out the required analyses, and it is interesting to consider the historical method of allocation of these funds among the various tasks. The bulk of such money--usually well above 50 percent and often 90 percent or more--has been traditionally spent on resource inventory. This has resulted in some excellent research findings, but much of the data obtained are often superfluous and quite irrelevant to the problems at hand (namely, siting, impact assessment, and mitigation of losses).

As stated by Christensen et al. (1975), "The primary goal of impact analysis is to provide information on which to base responsible decisions about a project." Presumably, the increases in our knowledge of ecosystems which result from baseline or impact studies can benefit wildlife by increasing the responsibility of decisions made regarding the effectiveness of various management strategies. However, cost-benefit analysis should be an important consideration in designing baseline and impact studies. Figures 11 and 12 graphically portray the costs and benefits of getting the information necessary to make a responsible decision. Here, the abscissa represents the costs of data acquisition (in terms of manpower, dollars, or both), and the ordinate represents the relative uncertainty associated with the parameter being estimated (whether a baseline parameter or a measure of impact probability). One hundred percent uncertainty implies no knowledge (e.g., we have no idea how many deer will be affected by a project), while zero percent uncertainty implies absolute

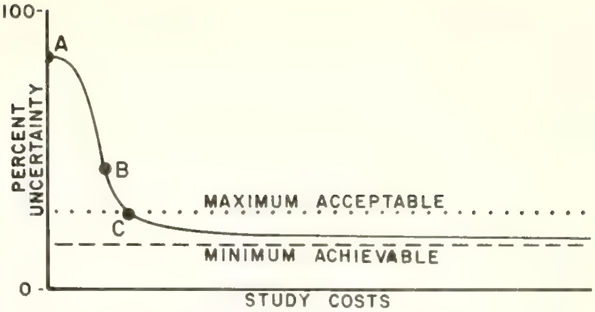

Figure 11.--The relationship between study effort and the relative degree of uncertainty in the parameter being measured.

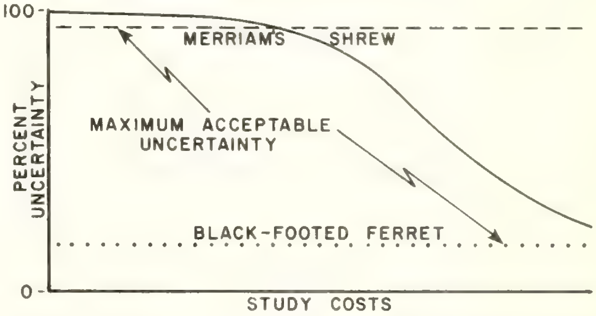

Figure 12.--For rare or hard-to-study species, a great deal of study effort is necessary to achieve an acceptable level of uncertainty.

knowledge (e.g., exactly 287 deer will be affected). Real-life situations fall somewhere in between: we think there is a 90% probability that 287 ± 29 deer will be affected. In figure 11, the dashed lines represent the minimum achievable uncertainty of our estimate; for example, it may be impossible to predict certain impacts with less than 10% uncertainty no matter how much we study them. The dotted line represents the maximum level of uncertainty we can accept in making a "responsible" decision.

Uncertainty may be decreased only by more intensive or extensive study, whether literature review or field work; of concern to us is the marginal cost of each incremental decrease in uncertainty. As an example, consider the curve in figure 11, which might represent a study of mule deer on a 20 mi^2 study area. If we know anything at all about the habitats of the area and the biology of mule deer, we may state immediately and with 90% certainty that the area supports between 3 and 212 deer--not a very precise estimate, but one which starts us somewhere below 100% uncertainty on the graph (Point A). Perhaps adjacent habitats have been well studied, and a few days of literature review and examination of vegetation maps will allow us to narrow our 90% estimate to 17-43 wintering deer without ever setting foot in the field (Point B). If this is still too imprecise to make responsible decisions, field work will be necessary. But, in this example, only a small amount of field work is necessary to achieve an acceptable level of uncertainty (Point C), and further effort is superfluous. Also notice that the curve approaches the minimum achievable uncertainty asymptotically, and that--at low levels of uncertainty-- a small decrease in uncertainty at the margin requires many years of study effort and great expense. It is our responsibility to determine if these costs are justified in light of the benefits, and whether this extra expense could yield more benefits if applied to enhancement, mitigation, or some mix of management techniques. We may even ask if a higher degree of uncertainty--and hence of risk--could be tolerated, if the study costs saved could be applied more effectively to enhancement. Perhaps the benefits to be gained through mitigation or enhancement would be greater than the maximum possible losses which could result from the project.

As an example, a modest three-year baseline wildlife study of a 20 mi^2 surface coal mining study area followed by monitoring for a 17-year project duration would result in costs on the order of $400,000. These costs include some 2240 man days of effort and 7.4 X 10^9 end use BTU's of fossil energy. It is possible that, if existing data and low-level reconnaissance were the only inventory data used in impact assessment, and if the remainder of the $400,000 were to be spent entirely on mitigation, compensation, enhancement, and related research, the net benefits to the resource would be far greater than those to be obtained by the best of baseline studies.

The cost-effectiveness of study, of course, varies greatly among different species. For example, the curve for rare, hard-to-study species such as Merriam's shrew and the black-footed ferret may look like figure 12. A great deal of field effort is necessary to know anything at all about these species, even whether or not they exist in the study area. However, we may want to be 95% certain (dotted line) that there are no ferrets in the study area before we allow strip mining, while we may tolerate 95% uncertainty about the shrew (dashed line). In this case, the relative value of the species enters into our cost-benefit analysis, which complicates matters immensely (see Ehrenfeld 1977).

As ecosystems receive more and more study, less inventory effort should be required for each new project, as existing data can be used. Still, inventory continues to consume the lion's share of funds available. Impact analysis, which usually consumes most of the remainder, typically constitutes little more than vague guesswork and discussion of the uncertainties involved in impact prediction. The reasons that these two topics generally use up the available funds are twofold. First, many laws clearly require such expenditures to be made before permits may be granted; once the company has the permit in hand, it is much more difficult to obtain funds for monitoring, mitigation, compensation, etc., since there is often no legal authority for doing so. Second, since inventory work usually precedes impact analysis, which in turn precedes mitigation studies, any overexpenditures or mismanagement of funds early in the process results in the money being used up before the key issues--mitigation and its relatives-- can be addressed. Resource managers all too often get caught up in the "inventory syndrome" and lose sight of the ultimate goal, which is to benefit--not necessarily to describe--the resource.

The point of this argument is not that we are studying wildlife too much, which is by no means the case; it is simply that assumptions regarding the relative cost-effectiveness of baseline study, impact analysis, and management techniques have often been accepted too casually.

CONCLUSION

Mitigation, compensation, and related strategies deserve more attention in project planning than they presently receive. In many cases, benefits to the resource could be greater if available funds were used more for these measures and less for traditional inventory and impact analysis. Cost-benefit analysis would provide an effective tool for optimizing these benefits, but the legal framework must be developed to allow resource agencies to identify and implement optimum strategies rather than traditional ones.

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Mitigation and the Forest Industry[1]

Robert L. Carlton[2]

The forest industry is concerned with the effects of implementation of the Fish and Wildlife Coordination Act on the nation's timber base. This paper presents an outline of industry's concerns, the nature of the impacts and suggestions on the mitigation process.

As seen by many in the forestry community, mitigation has become an issue of the acquisition of commercial forest land for the purpose of replacing, in part, the wildlife habitat lost to water resource projects. However, the issue of mitigation is only part of a much larger issue, the public acquisition of private lands. Unfortunately, as has been pointed out by Meyer (1979), we know very little about the actual dimensions of this problem. No one agency, public or private, is charged with keeping statistics on changes in land ownership and changes in land use. This may be the reason the United States has failed to foresee the problems which have arisen with land use and natural resources.

It is predicted that over the next several decades we can expect a doubling of the demand for timber. Whether this demand can be met or not is problematical. One reason demand may not be met is removal of forest land from productive management. In Oregon and Washington between 1945 and 1970, almost one million acres of commercial forest land were physically converted to non-forest use (Bolsinger, 1973); approximately 55 percent went into public or semipublic ownership for roads, reservoirs, and power lines. Of the 995,000 acres converted, 119,000 came from forest industry; approximately 89 percent went for roads, reservoirs, and power lines. During this same period of time, 362,000 acres of commercial forest land were placed in reserved categories such as parks, wilderness, natural areas, botanical areas, and other reservations and hence unavailable for timber production.

A study for the period 1955 to 1971 showed that approximately 164,000 acres of commercial forest land were cleared in New Jersey for a variety of purposes (Bones and Pierson, 1975). Rights-of-way and public use and recreation accounted for approximately 19 percent of that loss.

Material prepared for congressional oversight hearings on the Fish and Wildlife Coordination Act (House Serial No. 95-55, 1979) produced the following totals for authorized Bureau of Reclamation projects (in acres):

1. Normal project take line -- 2,775,873;

2. Normal conservation pool -- 486,561;

3. Mitigation lands within normal project take line -- 47,175;

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[1] Paper presented to the Mitigation Symposium; Fort Collins, Colorado; July 16-20, 1979.

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4. Enhancement lands within normal project take line -- 40,065;

5. Acres for mitigation outside take line -- 136,005;

6. Acres for enhancement outside take line -- 95,204.

This same source gave the following figures for the Corps of Engineers:

1. Project lands -- 2,483,959;

2. Conservation pool -- 931,126;

3. Wildlife mitigation acreage within project -- 335,961;

4. Wildlife enhancement acreage within project -- 33,675;

5. Wildlife mitigation acreage outside project take line --241,663;

6. Wildlife enhancement acreage outside normal take line -- 131,047.

Unfortunately neither the Bureau of Reclamation nor the Corps of Engineers breaks down its acquisitions, actual or proposed, by land use at the time of acquisition or proposal. Therefore, it is almost impossible to determine how many of these acres represent withdrawals from the commercial forest base.

In what follows, although the subject may be mitigation as mandated by the Fish and Wildlife Coordination Act, much of what will be said would apply to any other public works projects and the environmental mitigation which we can expect to accompany such projects in the future.

The main concern with past and current implementation of the Fish and Wildlife Coordination Act is that it has led to unnecessary losses of commercial forest lands from the area available for long-term timber production and use. Losses of private commercial forest land to water resource projects result from two major causes -- direct acquisition of lands and land use changes on other private holdings. Losses in the first category occur when lands are taken: (1) for project siting, and (2) to mitigate fish and wildlife habitat losses. Losses in the second category occur when landowners: (1) perceive new opportunities in such land uses as housing, agriculture and urban developments because of drainage, flood control, added water supply or power production from the project, and (2) convert forest land to other uses for fear these lands will be taken for mitigation if left forested.

Except for those relatively small areas of land converted to dams, roadways, and other similar structures, it is not accurate to speak of the loss of fish and wildlife habitat when listing the impacts of a water resource project. When a water resource project inundates terrestrial environments, these environments may no longer be available for deer, squirrels, rabbits, or other terrestrial organisms; however, the resulting aquatic environment becomes a part of the habitats of such species as bass, alligators, waterfowl, shorebirds, and other water-related wildlife. Therefore, the area has not been lost to fish and wildlife.

Instead, there has been a conversion from one kind of environment to another with changes in the kinds of habitats provided. Such conversions or substitutions may, or may not, be desirable depending upon the viewpoint considered. There are divergent views and interests between local and more distant users of project areas as well as varying opinions between those using different elements of the project environment.

Another misconception held by many is that federal or state acquisition of private lands increases available wildlife habitat. The transfer of title on a piece of land from one party to another does nothing to change the capability of that piece of land to support wildlife populations. Frequently, private lands acquired for wildlife habitat mitigation already furnish excellent habitat for wildlife, along with other important resource values and uses.

In general, with the exception of lands having values for waterfowl, acreage acquired for wildlife mitigation is transferred to state fish and wildlife agencies. The state agencies administering such lands often do not have sufficient funds to improve and administer these lands for wildlife. This inability of agencies to administer properly lands under their jurisdictions will create a situation less favorable to wildlife than if the land remained under private management.

Although a property right of one type or another has been acquired by the federal government in land for mitigation purposes, there are few data to indicate the extent to which acquisition of these interests has benefited wildlife. A major defect in mitigation programs is the failure to provide for collecting information on fish and wildlife habitats and populations before the project begins and after the mitigation program is implemented. This makes it virtually impossible to evaluate project and mitigation program impacts on fish and wildlife.

By the year 2000, the Forest Service has estimated that the demand for wood and wood products in the United States will double. This demand must be met from a constantly diminishing commercial forest land base. The United States can ill-afford the kind of single purpose acquisition and management which has been typical of the mitigation programs undertaken so far. Too often lands acquired for mitigation fail to provide the range of resource values previously available because of changes in management philosophy and ability to manage for a mix of outputs.

The forest industry believes that a need for changes exist, either in the statutes which establish requirements for mitigation, or in the manner in which these statutes are being implemented.

The forest industry believes that the following proposals would help correct many of the problems arising from public works projects:

1. Alternatives and Assessments. Project planning agencies should be required to list in clear, realistic and quantitative terms the objectives of any planned project. Once objectives have been established, the formulation, evaluation, and analyses of alternative ways of achieving the stated objectives should be made. For example, if the goal of a proposed project is flood control (more accurately, control of damage due to flooding), a major dam should not be the only solution given consideration; non-structural methods such as insurance, zoning, and watershed rehabilitation as well as other structural methods should also be examined. Although federal project agencies are now required to consider at least one non-structure alternative for achieving the objectives of water resource projects, it would be environmentally desirable if the majority of alternatives were non-structural, since these could be expected to have the least negative impact on the ability of the project area to provide natural resource values.

The impacts of a proposed project, and alternatives to it, on all the natural resources affected should be assessed early in the project planning process. The effects of a project on other resources, such as timber and water, should be assessed as well as those effects on wildlife habitat. Including consideration of all these natural resources early in the planning process should lead to development of ways to minimize effects on these resources and so reduce the need for natural resource mitigation.

For many sets of objectives, it should be possible to select an alternative which is cost-effective and has fewer adverse effects on natural resources. An alternative to a proposed project may be more cost-effective because it has fewer effects requiring mitigation.

2. Mitigation Costs. Costs for mitigation of project-related effects on natural resources should be a part of project costs. Mitigation costs must include monies for management to mitigate effects as well as for initial acquisition or construction for mitigation purposes. Project costs, including those for mitigation, must reflect that many of the natural resources adversely impacted are of a renewable nature; not only are the current standing crops of these renewable resources lost, but so are those crops which would be produced

in the future. Cost-benefit analyses must reflect that management costs for mitigation will continue for the life of the project. In addition, some type of environmental cost-benefit analysis, even if based on incommensurate values, must be developed for each project. Congress should not authorize any project unless the project plan includes the mitigation program to be implemented and all the costs for that program. Such costs must include the lost production of timber and other renewable resources through time that result from changes in management objectives.

3. Mitigation Program. The mitigation program for a public works project should be comprehensive, and the planning effort for that program should follow this sequence:

a. There should be a realistic, quantified assessment of the specific losses which likely will be incurred. The losses should be stated first in terms of the resources and secondly in terms of use foregone. For example, losses of deer habitat should be either in terms of deer habitat units or of deer lost, and only secondarily in terms of hunting days lost; timber losses should be stated in terms of cubic feet or board feet of wood fiber lost. This analysis should also include an assessment of the capabilities of the area to provide these values through time.

b. An evaluation should be made as to whether losses can in fact be mitigated. Because of the unique qualities of some sites, it may be impossible to mitigate their loss. In terms of wildlife habitat, for example, if a project completely floods river bottomlands, destroying key mule deer winter habitat in the area, this loss would be most difficult, if not impossible, to mitigate. If the factor restricting the numbers of a species in an area is further limited, it makes little sense to develop factors which cannot alleviate that situation. There should be recognition that there will be situations where no mitigation of the loss incurred is possible.

c. If losses which can and should be mitigated are likely, the following actions should be considered in order of priority:

(1) intensive management of existing federal areas to mitigate losses;

(2) intensive management of existing state areas to mitigate losses;

(3) cooperative agreements with private landowners to manage lands in order to mitigate losses;

(4) voluntary exchanges of private land, which could be managed to mitigate losses in the immediate area of the project, for public lands;

(5) easements or acquisition of other estates less than fee simple from willing sellers; and

(6) acquisition of fee estates from willing sellers of lands which are marginal for production of natural resource values.

These priorities reflect the forest industry's belief that when mitigation is necessary, it often can be accomplished by means other than acquisition of fee simple title to private lands. Most mitigation efforts to date have emphasized fee acquisition without exploring reasonable and effective alternatives. In fact, for many people, mitigation and land acquisition have become synonymous. As indicated, there are many other avenues which can lead to the same end result -- a reduction in the loss of natural resource values when public works projects are implemented.

When circumstances indicate that some degree of land use control over private lands is needed, the smallest estate which will achieve the mitigation objectives should be acquired. In many cases, what is desired is that lands be retained in their present land use. When this is the case, then only development rights on such lands should be acquired. Unfortunately, in many instances today, conservation easements and the guidelines for their implementation are such that the landowner's ability to manage his lands is seriously handicapped, and the landowner is often left only with the right to pay taxes.

If some interest in land is necessary, the more rational approach would be to acquire interests in lands which currently are not producing the natural resource values being lost to the project and to make inputs to increase the productive capacity of such lands. It would be reasonable to expect a much greater response in capacity for each unit of input on such lands than would be the case for lands already at higher levels of productivity. This would be wise land use.

4. Management. Mitigation must result in management of the remaining resources to increase the productive capacity of the area to offset that capacity lost to a project. Mitigation too often has meant, solely, land acquisition. The transfer of title from one party to another does not, in itself, increase the ability of land to produce the desired values. In too many cases, private lands which have been producing wildlife or other products suffer a loss in productive capacity following acquisition and transfer to a public agency. This happens because such agencies are underfunded to begin with and are unable to manage these added lands to increase their productive capacity. Steps must be taken to insure that lands used for mitigation of losses of natural resources have their abilities to produce such resources enhanced; this enhancement and the monies for it must be continued throughout the life of the project.

The forest industry is in basic agreement with the concept that whenever it is in the national best interest, reasonable and practicable steps should be taken to prevent the loss of natural resources as a result of public works projects. However, the ways in which such projects have been planned and carried out in the past have created difficulties for the forest industry and have demonstrated the potential for significant harm. Public works projects are withdrawing private lands from the commercial forest base and reducing the capabilities of the industry to provide the wood products needed by the American public. Because past efforts to mitigate natural resource losses have been ineffective, the forest industry believes the entire process of project planning, construction, and operation, including mitigation programs, must be reexamined and new approaches developed.

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The Economics of a Single-Resource Transferable Development Rights Mechanism[1]

Carl C. Mabbs-Zeno

and

William M. Park[2]

Abstract.--An alternative to the current case-by-case, ad hoc approach to mitigation with regard to coastal wetlands conversion is proposed. The single-resource TDR mechanism is shown to have advantages in terms of allocative efficiency and administrative cost, and potentially to be politically feasible.

INTRODUCTION

Coastal wetlands regulatory programs are currently being implemented by the U.S. Army Corps of Engineers, based on Section 404 of the 1977 Clean Water Act, and by state agencies in most coastal states. The approach of the Corps, as well as most of the states, involves case-by-case permitting. The existence of such institutional mechanisms suggests there was significant dissatisfaction with the way the unconstrained market system was allocating wetlands to preservation and development uses.

Economists expect private markets to fail in properly protecting environmental services, such as wetlands provide, because these services cannot generally be exchanged. Their value cannot be appropriated by private owners. The economic concept of externality refers to services which are external to market exchange. For example, the value of wetlands' provision of wildlife habitat is not reflected in the economic incentives of private wetlands owners. The owners are either providing an external be efit in preserving their wetlands or imposing an external cost in converting them to a developed use, depending on the property rights perspective taken. In any case the unconstrained market can be expected to allow "too much" wetlands acreage to be converted for developed uses, from a social welfare standpoint. There is clear justification for consideration of adjustments to the unconstrained market system t reflect the value of environmental services li the provision of wildlife habitat by wetlands.

However, institutional change which adjus or replaces the market system is not costless. Indeed, such change may entail relatively high administrative costs. In addition institutional change may lead to new externalities, unfavorable income distributional effects, and severe restrictions on freedom of choice. The real questions then are the following: (1) Is there a net social gain from a specific institutional change, i.e., are the benefits of a better allocation of wetlands between preservation and development greater than the costs of the institutional change? (2) Which institutional change results in the greatest net social gain? (3) Who bears the costs and receives the benefits of the change?

The classical method proposed by economis for dealing with externalities involves the us of taxes or subsidies to create incentives for landowners to treat externalities like factors normally considered in market exchange. When applied to wetlands this concept implies that wetlands owners would receive government payments equal to the external environmental benefits provided by their wetlands or that developers would be taxed by an amount equal to the

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[1] Paper presented at The Mitigation Symposium, Ft. Collins, Colorado, July 16-20, 1979, and based on a study which was funded as part of an Office of Sea Grant grant (04-6-158-44086) and (04-7-158-44086), National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The grant title is "Alternative Management Strategies for Virginia's Coastal Wetlands." More detailed information on the study can be obtained from the authors.

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ternal environmental costs imposed if their
etlands are converted. Again, the choice
uld depend on the property rights perspective
ken. Either approach would theoretically re-
lt in the economically efficient allocation
wetlands between preservation and develop-
nt which would maximize the social value of
tlands use. However, we are currently un-
le to measure the value of environmental ser-
ces very accurately. As such the practical
se for widespread use of such institutional
chanisms is weak. It should be noted, though,
at compensation for externalities in this
y would provide for an economically optimal
vel of mitigation, apart from administrative
sts.

The current approach to mitigation of the
fects of wetlands conversion instead involves
rmitting programs, some of which allow or re-
ire compensation-in-kind to be a permit condi-
on. Most probably have as their formal goal
e approval of only those proposals which will
ve positive net social benefits. However,
r inability to measure the value of environ-
ntal services, as noted above, only allows
rsuit of less formal goals such as preserving
sufficient base of wetlands acreage to be sure
at no severe environmental costs are imposed.

Banta and Nauman (1978) and Hershman and
otsola (1978) have indentified a number of
oblems with such an approach to mitigation.
e foremost is that compensation is determined
a case-by-case, ad hoc basis. This results
a relatively costly administrative process,
th significant delays and uncertainty; but
haps of more importance, it tends to ignore
cumulative or incremental effect of many
ojects. A second is that the relatively high
st burden imposed on developers may make
approach politically unacceptable. Compen-
ion can indeed be expensive when creation
new wetlands or adjacency of protected acre-
are required, or when full fee interest in
otected acreage must be transferred to a
lic agency.

This paper describes an alternative to the
rent approach to mitigation called the single-
ource transferable development rights (TDR)
hanism. It may superficially appear to be
ply a formalization of the compensation-in-
d requirement discussed above, and such re-
rements certainly do provide precedent for
However, closer examination will reveal
TDR mechanism's significant advantages
r the current approach in relation to the
blems identified above and other issues.
lowing a brief explanation of how the single-
ource TDR mechanism would work in practice,
will be compared, with the unconstrained
ket system as a base, to the current approach
terms of allocative efficiency, administrative cost, and political feasibility.

THE SINGLE-RESOURCE TDR MECHANISM

The conceptual roots of this institution lie in the idea of transferable development rights (TDR's), a mechanism which is consistent with the logic of compensating for externalities. TDR schemes involve separating ownership of the right to develop land from ownership of other rights in land. The common notion that a landowner can do anything with his land has been disrupted by the concept of land as a bundle of use rights or services, each of which may individually be sold or regulated. Development uses, as distinct from open space, agriculture, forestry, etc., are especially important because they generally involve permanent reductions in the land's capacity for providing other services of social value.

TDR schemes have generally been designed for use in preserving open space, allowing development rights in restricted land to be transferred to urban districts, in order to increase the density of development there above the maximum level otherwise allowed. In the case of the Puerto Rico Plan, as documented by Costonis and Devoy (1975), a TDR scheme was designed to preserve environmentally sensitive land, allowing TDR's to be used in urban districts. Schnidman (1978) discusses a 1974 zoning ordinance from Collier County, Florida which formally allows transfer of residential density from land designated for special treatment to contiguous areas.

The specific institutional mechanism suggested in this paper differs from the above in that development rights are transferred within a single resource category, wetlands in this case. For example, wetlands owners could be assigned one development right for each acre of wetlands owned. To convert one wetland acre for a development use would require two development rights; that is, it would require the developer to own the development rights from two acres. In this way, one acre of wetlands would be protected for every acre developed, guaranteeing preservation of at least half the existing wetlands acreage. If more or less than half of the existing wetlands acreage is desired for preservation, the number of development rights required to convert one acre would be adjusted up or down.

Allocative Efficiency

The fundamental notion of mitigation accepts that some wetlands will be converted to developed uses, but seeks to compensate in some way for the environmental services lost thereby.

As indicated in the discussion of permit programs above, the uncertainty in regard to the social value of environmental services suggests that a reasonable overall goal is to preserve a sufficient base of wetlands acreage so as to insure that no severe environmental costs are imposed. Surely we are in a better position to decide on how much wetlands acreage should be preserved overall than to estimate the net social benefits of individual projects. Though we cannot estimate the environmental cost of developing an acre of wetlands, we can be fairly certain that this cost increases as the stock of wetlands declines. As a result, there is likely to be a point at which the environmental costs of further conversion outweigh the development benefits, beyond which "too much" acreage is converted.

Minimum Acreage Guarantee

The single-resource TDR mechanism is designed to guarantee preservation of some proportion of the existing wetlands acreage. As such, the single-resource TDR mechanism has a real advantage over the current approach in relation to the problem of cumulative incrementalism. Under the current approach, approval of relatively small acreage conversions or specific types of projects without any requirement of compensation may set precedents which, over time, would allow conversion of "too much" acreage from a net social benefit standpoint. If permitting agencies are guided at all by the precedent of their own previous decisions, they will have difficulty ever rejecting permits for small acreages of wetlands conversion or specific types of projects and thus cannot guarantee a minimum permanent stock of wetlands.

Incentives To Account For Differing Development and Preservation Values

Within a constraint that some proportion of the existing wetlands acreage be preserved, maximum allocative efficiency occurs when the difference between the benefits associated with the development allowed and the environmental costs associated with the conversion of wetlands for this development is maximized. The primary determinant of a wetlands parcel's development value is location; the primary determinant of a wetlands parcel's environmental value for wildlife habitat is its biotic makeup. If, for example, half the existing acreage were to be preserved, it would be ideal if the half with the highest development location value also had the lowest environmental quality value. If this were so, the single-resource TDR mechanism would insure allocative efficiency, i.e., maximum net social benefits, without accounting explicitly for differing environmental quality among wetlands. Those wishing to develop the better locations would outbid thos wishing to develop the poorer locations for th necessary development rights. However, since it is unlikely that the best development sites are also the worst natural sites, the goal of TDR's is to encourage use of relatively high development location value and low environmental quality value wetlands when conversion for development occurs.

To accomplish this requires accounting fo differing environmental quality of wetlands. Several methods are possible. A simple procedure would be to define quality classes and make TDR's transferable only from the same or a higher quality class. This would insure that the acreage of the highest quality wetlan would remain at or above its current proportio of total wetlands acreage. Acquisition by the public or environmental groups of specific hig quality wetlands acreage could be used to complement the single-resource TDR mechanism.

The TDR institution could be alternativel modified to account directly for differences i value due to environmental quality by requirin more development rights to destroy higher qual ity wetlands. However, relatively high admini trative costs, including the information costs associated with the problem of precisely measu ing differences in the value of environmental services, prohibits doing this except on the basis of broad categories of quality. Some allocative efficiency relative to the hypothet ical ideal is sacrificed because there will re main some variation within quality classes. However, the administrative costs would most assuredly outweigh the allocative efficiency gains beyond some relatively broad level of categorization. Such a quality categorizatio which includes five groups of plant communiti has been developed for Virginia [Silberhorn, et al., 1974].

One other refinement of the TDR mechanis is suggested to account for wetlands quality. Some natural uses of wetlands do have a locational preference. For example, bird watcher and hunters of migratory birds value wetlands habitat more highly the closer it is to their homes, and certain fish species prefer salinities associated with the upper estuary rathe that with the ocean. TDR's can be made trans ferable only within geographic areas with dif ferent development rights requirements in eac area. In Virginia three regions consisting o the Eastern Shore penninsula, the lower Chesa peake Bay and the upper Chesapeake Bay would appear appropriate on the basis of this crite ion. It is important, however, that each are within which a market for TDR's will operate large enough in terms of wetlands acreage, th no individual or group is able to gain suffiient market power to abuse the system.

lexibility Over Time

An additional feature of the proposed mech-
nism which serves to improve long-term alloca-
ive efficiency is that specific wetlands acre-
ge is not protected when the development rights
ssigned to the owner for that acreage are used
or development. For example, suppose two de-
elopment rights are required to develop one
cre of wetlands. If development rights as-
igned to an individual for acre A and acre B
re used to develop acre A, acre B could still
e developed if someone, perhaps the same indi-
idual, purchased two additional development
ights which were assigned to an owner of wet-
nds acreage elsewhere. Thus, shifts in de-
elopment location values over time can be
comodated.

The single-resource TDR proposal then can
expected to provide superior allocative ef-
ciency, i.e., higher net social benefits,
an the unconstrained market system, due to
e constraint on the overall level of conver-
on and its ability to account for develop-
nt location value and environmental quality
lue to some degree. Its performance relative
the current approach can be expected to be
perior as well. As noted above, its constraint
the overall level of conversion gives it an
vantage in regard to the problem of cumulative
crementalism. In addition, the permit pro-
ss cannot be expected to determine which wet-
nds have the highest development value as
curately as the market does. It is in fact
e primary function of the market to process
formation so that land is allocated to its
ghest valued market use. The allocative ef-
ciency of the permit process is likely im-
oved to the extent that compensation-in-kind
used as a permit condition. However, re-
irements of strict adjacency and permanent
otection of specific acreages ignore the im-
rtance of location in development value and
e inflexible to shifts over time.

Administrative Costs

The relatively high cost in time and re-
urces to both public and private sectors of
e case-by-case permit process, which may in-
ude bargaining over compensation-in-kind re-
irements, is well documented. If a single-
source TDR system were set up, the public
ministrative costs would be relatively low,
marily accounting and enforcement. The wet-
nds inventories which would be required are
eady being done although land ownership is
dom recorded. Information and contracting
ts would be borne primarily by private developers; and as a result, there would be an incentive to minimize them. In addition, adjustment of the economic incentive structure within which free choice is allowed, rather than removing the wetlands use decision from wetlands owners as the current approach does, would reduce the likelihood of legal challenge as well as the public and private costs of legal proceedings. Though the single-resource TDR mechanism has higher administrative costs than the unconstrained market system, as any adjustment or replacement does, it would appear to have significantly lower administrative costs than the current system.

Political Feasibility

Though it might appear to many as another interesting, but unacceptable simple economic solution to a complex environmental problem, the single-resource TDR mechanism could gain the support of the several groups interested in the allocation of wetlands to alternative uses. In addition, it could be perceived as a marginal change from the current approach, involving formalization and generalization of the compensation-in-kind requirement, which is an important characteristic in relation to political feasibility.

Environmentalists

Though environmentalists might in general prefer to see absolute protection of all existing wetlands acreage, they might still prefer a single-resource TDR mechanism, with guaranteed protection of a high enough proportion of existing acreage and additional incentives for protection of high environmental quality wetlands, to the current approach. Specific wetlands acreage could, of course, still be purchased by the public or environmental groups for permanent protection. In addition, there is an incentive for creation of wetlands under the proposed mechanism if the price of development rights rises sufficiently, but not under the current system, unless explicitly required as a permit condition.

Developers

Though developers would in general prefer the unconstrained market system, they would likely favor a single-resource TDR mechanism with a low enough number of development rights required for conversion of an acre of wetlands, to the current system. The uncertainty of the permit process would be eliminated; and the time and resource costs of securing development rights would generally be lower than those associated with the permit process. The relatively high cost of meeting compensation-in-kind requirements would be reduced significantly, since only development rights rather than full fee interest in additional acreage need be secured; and this cost would be bounded by the cost of creating wetlands anywhere in the area.

General Public

Though perhaps the general public does not provide a constituency for allocative efficiency, the administrative cost reductions could lead the general public to favor the single-resource TDR mechanism over the current approach, since tax dollars are required to administer permit programs.

In addition, the single-resource TDR mechanism appears to have advantages over the current approach in terms of equity. As noted above, instead of taking the wetlands use decision completely out of the private property owner's hand, it adjusts the economic incentive structure within which free choice is allowed, so that the social value of personal freedom is retained. This eliminates discretion of public decision-makers and the opportunity for developers with political power to gain differential treatment.

Moreover, this mechanism moderates, if not eliminates, the "windfall-wipeout" phenomenon inherent in the results of a permitting approach. Those who are granted permits generally receive significant gains, while those denied permits receive nothing. One might also argue that such gain from location value is in part unearned, since it is largely a function of public infrastructure investment. The single-resource TDR mechanism spreads the net return from development of the proportion of wetlands allowed to be converted among all existing wetlands owners, not just those who own high development location value wetlands and are permitted to convert them, as in the current approach; or, to put it another way, the cost of wetlands protection, in terms of the opportunity costs of (benefits foregone by) not developing, is shared by all existing wetlands owners, not just those who are denied permits, as in the current approach.

Federal and State Agencies

In spite of its apparent advantages, federal and state bureaucrats may oppose the single-resource TDR mechanism relative to the current approach for several reasons. First, it would eliminate their discretionary authority in the permit process. Second, it would reduce their budget and manpower. Third, they might argue that it would not be consistent with their formal goal to allow conversion of wetlands f development only where the public benefits exceed the public costs. As discussed previously, the permit process cannot provide a rigorous benefit-cost calculation on each proposal The single-resource TDR mechanism provides fo meeting the spirit of such a goal by setting an overall constraint on wetlands conversion.

CONCLUSIONS

The single-resource TDR mechanism stands out as a promising alternative to the mechanism for mitigation within the current approac to coastal wetlands managment. It would appe to be superior to the case-by-case permit process, even where ad hoc compensation-in-kind requirements can be specified as permit conditions, on both allocative efficiency and admi istrative cost criteria. That is, it could b expected to provide higher net social benefit from the actual use of wetlands at lower administrative cost. Though institutional char is often difficult to foster, the single-resc TDR mechanism would appear to be politically feasible, based on consideration of the likel preferences of the important interest groups and its being only a marginal change.

Additional details would have to be work out in order to develop a specific TDR propos for coastal wetlands management. The recent experience of several communities with vario forms of TDR schemes would help to provide le and administrative guidelines and increased c fidence of success. The description herein the basic structure of a single-resource TDR mechanism should serve to stimulate further d cussion and more rigorous evaluation of its tential use in assuring that the social valu of coastal wetlands, or other environmental sources, is accounted for in use decisions.

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Biotic Recovery of a Reclaimed River Channel After Coal Strip Mining[1]

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and

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Abstract.--A newly constructed channel of the Tongue River, reclaimed with layers of gravel and medium cobble, pine snags, bouldered rip-rap, and rubble piles, was rapidly recolonized with stream invertebrates (70 days). Fish were only found in "snag" areas. Colonization curves predict attainment of a resident fish population in one to two years from channel opening.

INTRODUCTION

The Fort Union coal formation in the Northern Great Plains can potentially provide sufficient energy at present American consumption rates for 200 to 300 years (Freeman, 1975). Recent intensive mining operations in this area have caused considerable interest in impact of coal strip mining. Although land reclamation has been of primary interest, the impact on flowing waters through mine sites has recently been examined. Several large rivers run through the formation. These include the Yellowstone River and its tributaries, the Big Horn River, Rosebud Creek, the Tongue River, and the Powder River. Because the Tongue runs through the greatest portion of the formation, it has suffered the greatest strip mine impact. Indeed, with seams being at depths of two meters in some places and often at the level of the substrate of the river, the Tongue has been diverted in order to strip the original stream bed. Under the Surface Mining and Reclamation Act of 1977 (SMCRA, 1977, P.L. 95-87), if possible, the river was to be returned to its original channel.

Arising in the Big Horn Mountains of Wyoming, the Tongue River flows northeast through the Big Horn Mine, Sheridan, Wyoming, into Montana where it has its confluence with the Yellowstone River. At the Big Horn Mine, the river had been diverted into a previously mined pit (Brown-Williams Pit) for several years. In 1978, the river was returned to its original channel configuration. According to recommendations of Wesche (1974) and Cooper and Wesche (1976), the channel was cut and graded to its approximate pre-mining configuration and gradient. Banks were hydromulched and planted with various combinations of grasses and local riparian trees and shrubs. The substrate of the channel contained layers of topsoil, gravel, and small to medium cobble (32-129 mm diameter). Embankments were lined with large, angular "quarried" boulder rip-rap at the estimated average water line. A predicted uniform depth of 46 cm of water was to run through the new channel. At intervals along the length of the channel, large boulders (3 meters diameter) were placed in the thalweg to provide pooling and cover for potential fish invaders. In addition, pine trees were anchored into the bank and substrate to act as "snags" to provide additional cover for fish invaders. An example of a reclaimed section is shown in Figure 1.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Research supported by contract and agreement with Peter Kiewit Sons' Co., Mining District, Sheridan, Wyoming and Rocky Mountain Institute for Energy and Environment, Industrial Fund.

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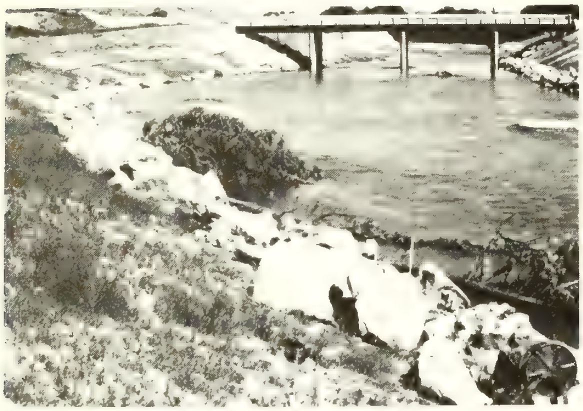

Figure 1.--View of a typical reclaimed portion of the Tongue River.

Because the channel was reconstructed from materials not originally associated with the channel, it acted as a "new" island to be colonized. This island allowed us to examine the colonization postulates of MacArthur and Wilson (1967) and their application to aquatic ecosystems. Predictions of attainment of equilibrium density of benthos have varied from 14 to 21 days (Sheldon, 1977; Khalaf and Tachet, 1977) to 120 or more days (Williams and Hynes, 1977). Fisheries colonization had been shown to be by young-of-the-year (Krumholz and Minckley, 1964; Gunning and Berra, 1969) and that sport fish could take several years to invade the area (Larimore, Childers, and Heckrotte, 1959). With the exception of one study (Olmsted and Cloutman, 1974), Centrarchids, being highly territorial, were found to be the most delayed invaders.

FIELD METHODS

Six sampling stations were established to include upstream and downstream areas of the new channel of the Tongue River and an upstream area of the new channel on Goose Creek, an upstream tributary. Three channel sample sites were established.

At each site, macroinvertebrate samples were taken using a 0.1 m^2 Hess sampler (Waters and Knopp, 1961). Samples were taken daily for the first 15 days after the new channel opened on August 8, 1978. Four weeks after the initial sampling period, and each succeeding fourth week, benthic samples were taken at each site. Monthly sampling continues until December 1979. Each of the samples was sorted, counted and identified to lowest taxonomic level.

At intervals of five days during the initial period of channel opening and during subsequent four-week intervals, fish in the new channel were collected using electrofishing equipment. Markers, made of species color-coded styrofoam balls attached by monofilament line to concrete weights, were placed at the spots of fish collection. Fish locations were mapped for future assessment of efficacy of various improvement structures. During the initial 15 day period, game fish and some forage fish were transplanted from the Brown-Williams Pit to the new channel. Each individual was fin clipped for recognition in future samples.

METHODS OF ANALYSIS

A "target" or approximate equilibrium density was established by deriving a mean density for benthos at undisturbed upstream and downstream stations and for fish by comparison of numbers from inventories in the channel area.[5] At each of the channel stations, the trends in increasing density were analyzed with the object of fitting a curve equation to the density increases as they approached the equilibrium density. Standard regression analysis was used to determine approximate curves and then checked with chi-squared goodness-of-fit tests (Chapman and Schaufele, 1970).

Trends in diversity were analyzed by three methods. At undisturbed sites, a mean diversity was calculated as a "target-equilibrium-diversity" using the Shannon-Weaver index (H') (Pielou, 1975). Curves were fitted to the trends in diversity (H' and S, the number of taxa per sample) as they approached equilibrium. An even-ness index was used to assess possible dynamic changes within the community after attainment of equilibrium density. This index (E) predicts the greatest possible diversity derived from the number of species in that sample (Sheldon, 1969). Trends in E gave an indication of establishment of a community similar to those in undisturbed areas.

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RESULTS

Benthic colonization at the various channel stations started quite slowly but was increasing rapidly by day 15 after channel opening. By day 70 (see discussion, Figure 2), densities comparable to undisturbed areas had been achieved. Diversities did not reach an equilibrium point until day 90 (Figure 3).

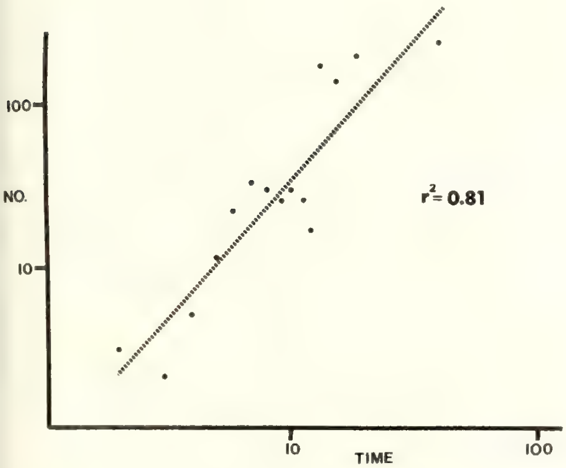

Figure 2.--A typical benthic colonization curve (power function) for the Tongue River new channel. Numbers of invertebrates. Time in days from channel opening.

The primary benthic colonizers were the mayflies *Baetis parvus* and *Baetis alexanderi*. These animals were also the dominants in the undisturbed areas. During the change to a winter benthic community, the dominant in the undisturbed areas changed to the mayfly, *Ephemerella inermis*, and various species of the net-spinning caddisfly, *Hydropsyche*. These changes in community dominance were also shown in the new channel but lagged the undisturbed areas by about 20 to 30 days. The early summer benthic community, 1979, in both undisturbed and new channel sections were of comparable densities and diversities on simultaneous sampling dates.

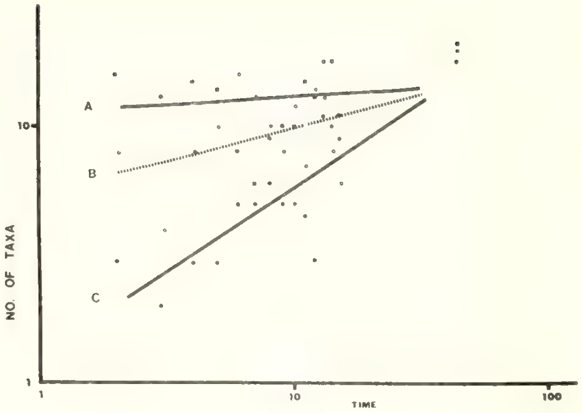

Figure 3.--Trends in benthic diversity over the initial colonization period. Time in days from new channel opening.

Fish colonization increased rapidly during the initial 15 day sampling period and leveled off during subsequent sampling periods (Figure 4). White suckers (*Catastomus commersoni*) and longnose suckers (*C. catastomus*) were the primary fish colonizers. By day 15, the first game fish began to appear in the new channel. These colonizers, rock bass

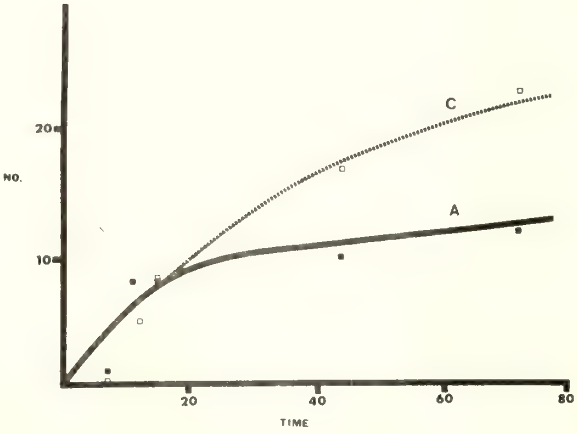

Figure 4.--Colonization trends (polynomial) for fish at stations in the new channel of the Tongue River.

(Ambloplites rupestris), yellow perch (Perca flavescens), and stonecats (Noturus flavus), which were marked with fin clips (subsequently with Floy tags) have not reappeared in subsequent samples. "New" invaders were found in each subsequent sample. By day 70, several cyprinid species, and game fish, smallmouth bass (Micropterus dolomieui), green sunfish (Lepomis cyanellus), and sauger (Stizostedion canadense), were also found in the electrofishing runs. Fish were all found inhabiting backwater areas behind the "snagged" trees. One snag area was lost to fish colonizers when water levels dropped at this area. As time progressed, the configuration of the lower end of the new channel was changed by diking of the closed off Brown-Williams Pit. This increased the depth of the lower channel areas to about 1.5 meters, inundating the large boulder rip-rap. These areas became primary collecting points for the smallmouth bass. After ice cover breakup in the spring, we found many of the large boulders in the new channel to have fractured during the winter. These rubble piles were cavitating rapidly. White suckers were found to be inhabiting the backwater areas of the rubble piles during electrofishing samples, spring, 1979.

Of the 51 game fish transplanted to the new channel, only two yellow perch were found to have remained in the channel. Each was found only once after the transplant operation.

DISCUSSION AND ANALYSIS

A typical colonization curve for benthos is shown in Figure 2. Correlation at all stations showed a high degree of reliability. Chi-squared values were all less than 5.23 ($p < .05$). These curves fit the predicted power function equations of Sheldon (1977). This equation:

$$N_t = at^b$$

predicted equilibrium densities would be achieved on about day 45 to 70. Indeed, these were the approximate times (upstream to downstream) that maximum densities were attained.

The benthic colonization mechanism appears to be drift from upstream areas. This type of colonization is typical (Williams, 1977; Williams and Hynes, 1976, 1977).

The crane fly, Hexatoma, was a member of the Tongue River upstream community and the dragonfly, Ophiogomphus morrisoni, appeared only in the downstream Tongue River samples. The pit apparently acted to isolate these members from further redistribution. These two species were used to assess the relative contribution to colonization by drift and upstream migration. By day 14, Hexatoma appeared consistently in the channel communities. Ophiogomphus began to appear regularly at the downstream and midway channel stations by day 90. It appears, then, that the greatest contribution to colonization was by drift. Upstream migration has been previously reported (Bishop and Hynes, 1969). Indeed, Gore (1977) has shown benthic invertebrate migration in the Tongue River of up to 40 km in a period of three weeks. In the new channel, the slower rate of migration by Ophiogomphus can be attributed to competition with the more rapidly increasing numbers of aquatic insects in upstream stations provided by drift.

The lag in maximum benthic diversity compared to density (Figures 2 and 3) has been observed in other colonizing communities, particularly birds on new islands (MacArthur and Wilson, 1967). MacArthur and Wilson predict that this "lag" period represents a period of dynamic adjustment within the community to the dominance structure of comparable undisturbed areas. Simberloff (1978) suggests that this adjustment phase is a result of partitioning of available resources in invertebrates.

The sequential downstream increase in slope of colonization curves (Figure 3) is previously unreported, although Sheldon (1977) intimates that this is a predictable consequence of a linear arrangement of colonization areas. The variable drift rate of various aquatic insects (McLay, 1970) and the variable drift rate of non-living material (De La Cruz and Post, 1977) explain this phenomenon. The process of greater kinds of invertebrates and non-living material settling at upstream channels during channel opening imply the effect of sequentially increasing habitat complexity with time as a function of distance from the upstream colonizer source areas. Until the entire channel reached stability, each station downstream had progressively simpler biotic and abiotic structure until short-drift-distance items reached those points.

Instead of power functions, fish colonization curves (Figure 4) fit third order polynomials such that (example):

$$y_A = .18 + .55x - .01x^2 + .00009x^3$$

These curves predict attainment of equilibrium in one to two years. These are trends similar to those predicted for vertebrates by MacArthur and Wilson (1967). The more downstream areas showed a more rapid recolonization than upstream areas (Figure 4). This indicates that colonization was primarily by upstream migration. Although previous reports (Kennedy, 1955; Gunning and Berra, 1969) reported greater portions of juveniles and young-of-the-year occurring in new fish communities, we found a rather homogeneous mixture of age and size classes appearing in the new channel. Like Olmsted and Cloutman (1974), we found many centrarchids to be early game fish invaders. This may be a reflection of cryptic behavior in sub-adults who are then able to invade new territory when it becomes available.

Generally, game fish represented only a small portion of the fish collected on each sampling date. Because most game fish are predators (particularly in a warm water fishery like the lower Tongue), they will only colonize a given area after a forage fish and/or stable macroinvertebrate community has been established (Larimore, Childers, and Heckrotte, 1959). Thus, we anticipate establishment of a game fishery only after a resident forage fish community has been established.

CONCLUSIONS

As a general assessment of the reclamation to date, we feel:

1. The substrate of the new channel (medium and small cobble) is a good colonizing surface for macrobenthos. This is indicated by the simultaneous occurrence of the 1979 early summer communities in the channel and in the undisturbed areas, showing successful recruitment in the channel.

2. Time of establishment of a stable macroinvertebrate community is a function of the length of the channel and distance from the upstream source area.

3. The "snag" areas provided the best cover for fish colonizers during initial flow in the new channel.

4. The large boulders placed in the channel provided good fish cover only after winter-freeze fracturing into rubble piles and cavitation occurred.

5. Because inundation of rip-rap provided effective fish habitat, we suggest additional large boulder placement in slow water areas of three or more feet in depth, for this purpose.

6. Fish community stability will be attained in from one to two years after new channel opening.

7. Channel and substrate stability (sinuosity and cementing, respectively) must be maintained to effect final biotic reclamation.

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Coal Mining Reclamation in Appalachia: ow Cost Recommendations to Improve Bird/Wildlife Habitat[1]

Pierre N. Allaire[2]

Abstract.--Mountain-top removal mining in eastern Kentucky and subsequent reclamation into grassland communities has produced drastic changes in the birdlife. Certain uncommon grassland birds have become common nesting species. A greater diversity of migrant species has also been noted. Mountain-top removal recommendations include creating rolling topography, building ponds, increasing seeding rates, bird nest-box program and managing grasslands.

INTRODUCTION

Over the past three decades research reated to birds on surface-mines has been inreasing steadily. Gamebirds have been of nterest because of the economic potential they ffer. Verts (1956) evaluated wildlife options rom stripped areas in Illinois. He found, as limstra (1959, 1962) did, that these areas ffer a potential for this kind of activity. tudies by Vohs and Birkenholz (1962) and Brown nd Samuel (1978) have demonstrated that Bobwhite *Colinus virginianus)* can use these areas if anaged properly. Kimmel and Samuel (1978) eported on the use of surface-mines by Ruffed rouse *(Bonasa umbellus)*. Bukenhofer (1977) xamined the food habits and densities of ourning Doves *(Zenaida macroura)* on strip-mines n eastern Kentucky. Samuel and Whitmore (In ress) investigated the management potential f surface-mined areas for game birds in West irginia. They recommended a variety of manageent techniques for Mourning Doves, Bobwhite, oodcock *(Philohela minor)*, Ruffed Grouse and urkey *(Meleagris gallopavo)*. Rafaill and ogel (1978) published a guide for vegetating urface-mined lands for wildlife in eastern entucky and West Virginia. The guide offers uggestions on plant species, seeding methods and soil amendments to promote wildlife. Sandusky (1978) demonstrated that waterfowl can breed on these areas. Mallards *(Anas platyrhynchos)*, Wood Ducks *(Aix sponsa)* and Blue-winged Teal *(Anas discors)* were successfully reared on reclaimed surface-mine ponds.

Investigations relating to the nongame avifauna of reclaimed surface-mines has only recently become available. The research has fallen into two categories. First, there are studies that were conducted on areas naturally revegetated by pioneer species. Brewer (1958) reported on the breeding bird population on a Perry County, Illinois mine site. Karr (1968) investigated the relationship between habitat diversity and avian diversity during the breeding season on strip-mined land in east-central Illinois. Jones (1968) gave detailed field data, encompassing a 12 month period, on the birds of some strip-mined land in southern Indiana. More recently Chapman et al. (1978) analyzed breeding bird populations in response to natural revegetation of some abandoned contour mines.

The second category deals with surface-mines that have been revegetated through reclamation techniques, such as tree planting and hydroseeding (i.e., the broadcast of seeds, fertilizers, wood fiber mulch, and water all in a single application). Fields of mixed grasses and legumes are commonplace today where mining has occurred within the past eight years.

Stromer et al. (1978) assessed grass/legume reclamation of iron ore tailings basins in

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[1] Paper presented at the Mitigation mposium, Fort Collins (Colorado State Univerity), Colorado, July 16-20, 1979.

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Michigan. Seventeen species of birds bred in his study areas. Cantle (1978) studied the population densities and species diversity of birds on reclaimed lignite mines in east-central Texas. He found that his reclaimed areas were lower in bird density and diversity when compared to unmined areas nearby. Allaire (1978) and Whitmore and Hall (1978) discussed the potential of certain nongame grassland species on reclaimed surface coal mines in Kentucky and West Virginia, respectively. The creation of this kind of habitat where none or little existed before mining has attracted a variety of birds that are rather unusual for such parts of their states. Whitmore (1978) offers suggestions on managing reclaimed surface-mines in West Virginia to promote nongame birds. He stresses the importance of managing these areas for the sake of ecological diversity. I (Allaire 1979b) have also found this to be true. According to preliminary results, I am of the opinion that birds can be quite useful in the process of land use planning of reclaimed surface coal mines. Birds offer economic and aesthetic benefits not realized by most people.

The purpose of this paper is to promote the idea that reclaimed coal mines in Appalachia are not wastelands, at least not those mined within the past five to ten years where companies have made a conscious effort at reclamation. Breeding bird data, already mentioned, show that reclaimed mines attract and support bird species that are quite different than those of the surrounding forest. Observations during the spring and fall migratory seasons (Allaire 1974, 1975a, 1975b) have revealed that grebes, herons, geese, ducks, shorebirds and grassland species stop in these areas during their long journey. Data on birds utilizing reclaimed mines during the winter are sparse (Terrel and French 1975, Green 1975, Allaire 1979b); further investigation is needed.

Managing these areas for birds and wildlife should include a plan to create a diversity of habitats. Sprunt (1975) emphasizes this point very clearly. Verner (1975) believes that an understanding of avian behavior is paramount to management. I have incorporated both philosophies into the five recommendations listed in this paper. A major goal of this research is to promote the implementation of some or all of these recommendations.

STUDY AREA AND MINING METHOD

The recommendations outlined in this paper are based on four years (March 1974 to July 1978) of data collected from three reclaimed surface coal mines in Breathitt County, Kentucky. The area is mountainous. Elevation of these mined sites range from about 300 m (990 ft) to 450 m (1485 ft) with slopes betwee 15 to 30 degrees. Numerous trips to these study areas to census birds during all four seasons have provided data on those species breeding, migrating and wintering on these reclaimed mines.

The general topography lends itself well to the mountain-top removal (MTR) mining method. The tops of the mountains are mined to uncover the seams of coal that lie underneath, resulting in a flattened mountain. Reclamation of these mines, using mixtures of grasses and legumes, results in grassland fields surrounded by native forests. Habitat such as this is quite unusual for the higher elevations of the Appalachian Mountains.

The MTR mining method offers a potential for incorporating wildlife management practice. In general, coal companies that perform this type of mining have the heavy equipment necessary to shape the land into useful configurations for wildlife. Occasionally some operators have reclamation supervisors who are trained in planning for wildlife. They pre-plan thei wildlife management objectives into the reclamation itinerary. The results are usually rewarding.

In this paper I propose to demonstrate that reclaimed surface coal mines in areas where MTR are performed can enhance birdlife at little cost to the coal operator. The key to keeping costs low is to pre-plan the reclamation itinerary. Any one or all of the recommendations may be suitable for a specifi job site, however, the operator must make tha decision. In general, he can find at least o recommendation that is feasible.

RECOMMENDATIONS AND DISCUSSION

Each recommendation section is divided into two parts. First, the recommendation is presented. A brief explanation follows describing how the coal operator may achieve the recommendation on MTR operations (all recommendations are applicable to area-wide mines i flat, unmountainous regions also). Second, a description of those bird species utilizing these areas at various times of the year and the ecological requirements of why they are there is discussed. The list of species mentioned is by no means complete. Composition of bird species varies throughout Appalachia. Important, however, is the fact that when certain kinds of habitat are created, for example grasslands, then grassland species in the area generally utilize available habitat.

1. A rolling topography where water may collect to form shallow puddles, mudflats, or temporary ponds should be created.

A landscape such as this can be easily achieved if the job foreman at the job site instructs his bulldozer operator(s) to do so during the final grading. Slight relief of "hills" and "valleys" will form natural drainage basins where water may accumulate at depths of 15 cm (6 in) to 30 cm (12 in). If pyritic materials in the overburden cause acid problems then this kind of topography should not be left. However, toxic materials are usually buried, leaving an overburden with a pH between six and eight. Figure 1 shows a reclaimed mine that fits this type of landscape architecture.

A wide variety of birds were found frequenting areas, like that shown in figure 1, throughout the study period. In the summer, Barn *(Hirundo rustica)* and Rough-winged swallows *(Stelgidopteryx ruficollis)* often drank from these puddles. Flying insects that concentrated near these mudflats provided food for flycatching species of birds such as Eastern Kingbirds *(Tyrannus tyrannus)* and Eastern Phoebes *(Sayornis phoebe)*.

The spring and fall migratory periods were the times when bird species and numbers of individuals were the most numerous. Fourteen species of plovers and sandpipers were observed. Mudflat areas, like these, are quite similar to the breeding grounds where many of these shorebirds breed in the arctic. They find this habitat particularly attractive when in migration. Five species of swallows and Purple Martins *(Progne subis)* have been seen drinking and foraging over these areas. If cattails *(Typhus* sp*)* are present, marsh wrens and rails sometimes utilize these sites. The Water Pipit *(Anthus spinoletta)* is another common migrant often seen.

The winter is not an especially good time for birds in this habitat. The mudflats dry up in late summer and the remaining water freezes over.

Basically, these shallow ponds or mudflats are similar to the breeding grounds (if the bird is going north) or wintering grounds (if the bird is going south). The addition of this new type of habitat in the mountainous Appalachians adds a new dimension of ecological diversity not present in this predominantly forested part of the country.

2. Water impoundments, at least one-half hectare (1+ ac) in size, should be built whenever possible and preferably terraced along the inside embankment.

As in recommendation number one, the job foreman need only instruct his heavy machine operators to incorporate a pond in the final grading just prior to revegetation. Not only is it useful for wildlife but these ponds can also be used for watering cattle, irrigation and providing a nearby source of water for hydroseeding.

Water is a necessary part of any living organism. When the MTR is involved, water is

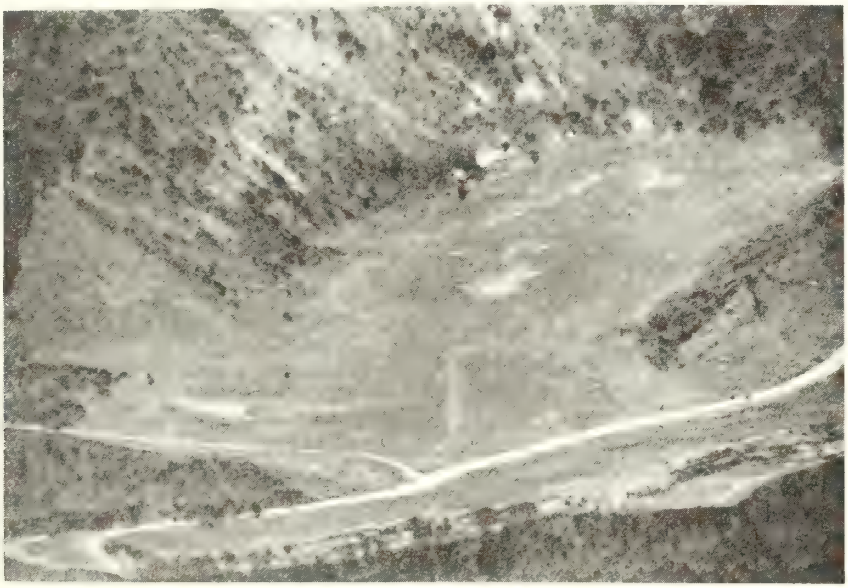

Figure 1.--Aerial photograph of a 16.6 ha (41 ac) reclaimed mountain-top removal area in Breathitt County, Kentucky. During migration the pond on the right attracted waterfowl. The two mudflats to the left were frequently used by shorebirds.

usually scarce because it never has anywhere to accumulate. Most of the water runs down into the valleys. Consequently, lack of watering holes is a negative aspect to reclamation planning. Perhaps in the future more consideration will be given to ponds.

Breeding birds from the surrounding area come in to drink from the ponds. If cattails are present along the pond edges Red-winged Blackbirds *(Agelaius phoeniceus)* and Common Yellowthroats *(Geothlypis trichas)* nest there.

Migratory ducks and geese were observed in small flocks during the spring and fall; sixteen species in all. Aquatic invertebrates (mostly insects) and plant material are the main food sources. Occasionally, shorebirds are found feeding along the shoreline's edge. Swallows and martins drink and forage over the ponds as they do over the marshes and mudflats. If stocked with fish, herons and egrets should be found feeding where the water is shallow.

During the colder months the ponds freeze over, at least in eastern Kentucky. Once frozen the ponds are of little value to wildlife.

Improved designs of water impoundments atop MTR reclamation sites could increase bird utilization and diversity throughout migratory and breeding seasons. Figure 2 represents a water impoundment that contributes to the ecological requirements of most aquatic and semi-aquatic birds known or thought to occur in the Appalachians. Drainage must be calculated and correlated with average annual rainfall in order to provide the amount of water needed to fill the pool. Width and length are also crucial. One group of birds, the loons, need long "runways" of water to get airborne; the minimum size is approximately 50 m (165 ft) by 200 m (660 ft). The shape can be irregular and does not have to be perfectly rectangular. One option is to make one side or 25 percent of the perimeter steep-sided. The purpose is twofold: first, if the area is stocked, pan fish prefer areas where there is little emergent vegetation growing; second, fisherman would have access to the pond's edge where casting along the edge would be ideal, since vegetative growth along the edge would be minimal. The open water in the central portion of the pond must be at least 1.6 m (5 ft) deep.

Pond ducks prefer deep water. The rock island would serve as a resting area. Notably gulls and terns often find such sites appealing when migrating. The terraced sides with the shallow water would serve to increase shoreline habitat for wading birds and sandpipers. Areas where cattails would invade could be utilized by rails, marsh wrens, yellowthroats and red-wings.

One habitat feature noticeably absent near any of the study ponds was perches. Numerous migrant bird species could find use for a perching site above water. The illustration (fig. 2) gives the impression that the cable or rope be placed directly over the center of the pond. Moving the cable elsewhere, as long as some portion of it goes over the deeper water, should pose no problems. Data from this study show that flycatchers, swallows, robins, bluebirds and red-wings use rope perches on surface-mines when available. Other species that could be expected to use perches include Ospreys *(Pandion haliaetus)*, terns, Belted Kingfishers *(Megaceryle alcyon)*, Loggerhead Shrikes *(Lanius ludovicianus)* and Bobolinks *(Dolichonyx oryzivorus)*.

3. *Increase seeding rates of grasses and clovers to the highest number of kilograms (pounds) per hectare (acre) that is economically feasible to provide improved breeding, migratory and wintering grounds for birds.*

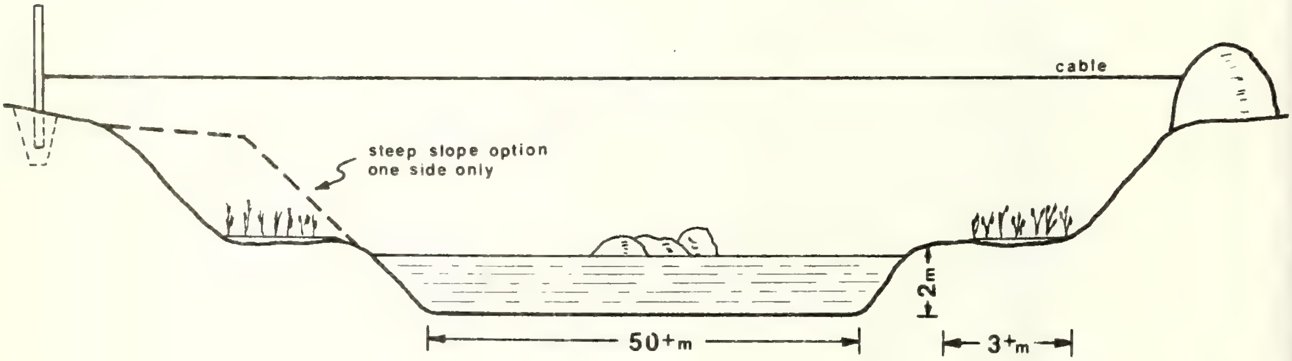

Figure 2.--Multipurpose pond designed to attract a wide variety of birds on reclaimed surface coal mines.

Coal operators could easily plan to double or triple the amount of grasses and clovers when hydroseeding certain areas in order to establish a good grassland stand of vegetation. I do not advocate this approach for 100 percent of any company's reclamation program. Rather, this increased seeding program perhaps can be applied to 20 percent of their operations. Despite the additional cost in seeds, fertilizers, mulch, etc., most companies should be able to contribute this extra expense.

Grasslands that have high stem density generally have a good variety of grassland species breeding on them. Many species, like the Grasshopper Sparrow *(Ammodramus savannarum)* and Eastern Meadowlark *(Sturnella magna)*, obtain insects that feed on the grasses and clovers as their principle summer food. The young in the nest are also fed an insectivorous diet. Lush grasslands can provide a sufficient amount of insects to sustain mixed populations of grassland bird species.

Migratory species, particularly the sparrows, have been observed in large numbers feeding on reclaimed grasslands in eastern Kentucky. At these times of the year the diet of most grassland birds changes to seeds. Many birds would benefit by having grassland areas that were high in seeds. Increased seeding of certain locations would provide good foraging areas.

Preliminary results (Allaire 1979b) indicate that reclaimed surface coal mines are poor wintering areas for birds. Doubling or tripling seeding rates in 20 percent of a coal company's operation would produce "grassland islands" with abundant food (seed) reserves available during the harsh winter months.

4. *Initiate a program to erect bluebird nest boxes on reclaimed surface coal mines.*

Bluebird nest boxes can be made economically and *en masse* (South Carolina Wildlife 1975, Zeleny 1977, Patterson 1979). Placed atop black locust *(Robinia pseudoacacia)* or other suitable posts (1.7 m to 2.0 m above the ground and preferably near a surface mine pond), these nesting sites provide a critical element in the survival and continuation of this species. Natural nesting cavities have been disappearing over the past few decades. Establishment of a nest box program by coal operators by building and supplying the boxes to any group interested in placing them on reclaimed mines, by supplying the materials to interested groups for construction of the boxes, or by providing access to reclaimed areas to groups or individuals who have their own boxes, would be a worthwhile endeavor for any company.

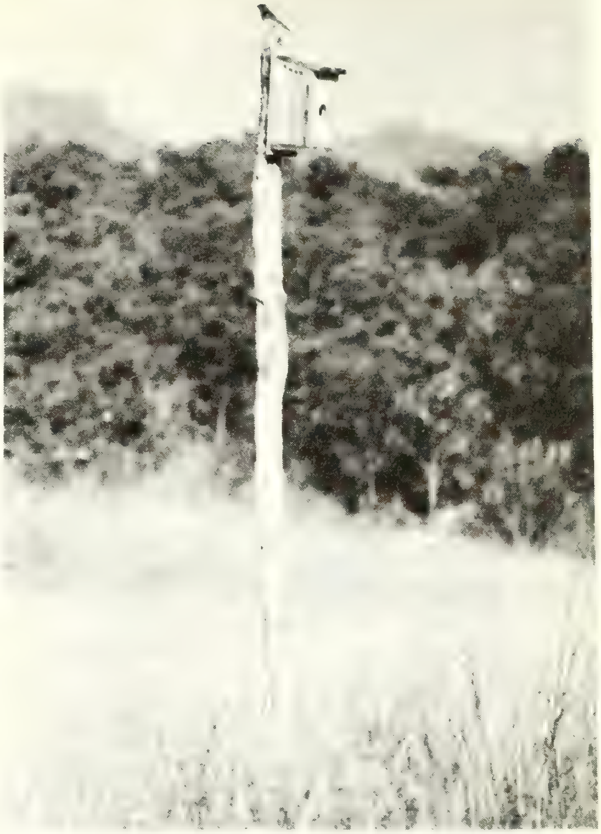

Figure 3.--A bluebird nest box placed on a reclaimed surface coal mine in Breathitt County, Kentucky. A male Eastern Bluebird is perched atop the nest box.

Eastern Bluebirds *(Sialia sialis)* have been one of the most interesting species encountered utilizing the reclaimed areas in eastern Kentucky. Bluebirds have nested in hollow locust posts, pipe fencing and highwalls (Allaire 1979a). Nearly all the nest boxes erected by a local coal company have had one and sometimes two broods a breeding season. Figure 3 shows a male Eastern Bluebird perched on a nest box. The female was inside incubating a clutch of eggs.

5. *Maintain a certain amount of grassland habitat on reclaimed surface coal mines through light grazing, periodic mowing or controlled burning for the purpose of ecological diversity.*

Although the coal operator is not responsible for the land after the bond is released he can suggest land-use options to the land owner. Any of the methods mentioned above are sufficient to maintain grasslands without having them revert back to forest.

I do not condone mining every mountain so so that there can be huge amounts of flat, rolling grassland in Appalachia. Some of the land should be allowed to return to forest. However, for the sake of ecological diversity, I believe grasslands are important. A case in point: one species of bird that has benefitted by light grazing on reclaimed surface-mines has been the Grasshopper Sparrow. During three years of field research on my study areas in Kentucky this species has bred successfully (Allaire 1979b). The same is true on some West Virginia reclaimed surface-mines (Whitmore and Hall 1978, Wray et al. 1978). These small isolated populations may be significant, in light of recent population declines in many parts of the United States. Arbib (1978) considers this bird a Blue List species. He reported that 72 percent of the respondents surveyed stressed that loss of habitat through plowing of prairies or meadows and mid-summer mowing (I suggest late-summer to early-fall) has seriously threatened this species. Others believe that this species is severely affected by DDT and other long-lived pesticides. What has happened over the past decade on reclaimed surface-mines in Kentucky is analogous to the situation of the range expansion of the Grasshopper Sparrow in western Pennsylvania over a century ago (Todd 1940). The species has spread beyong its normal range as a result of the cultivation of the land for pasture and hay. Smith (1963) points out that Grasshopper Sparrows appear to be most abundant on cultivated croplands that have orchard grass *(Dactylis glomerata)*, alfalfa *(Medicago sativa)*, red clover *(Trifolium pratense)* and bush-clover *(Lespedeza* sp*)*. Their bunch-forming growth seemingly are required by this species. In light of this evidence, reclaimed surface-mines may well be important areas for continued existence of this and other species that are affected by pasture and agricultural practices uncommon in this type of habitat.

Overall, nongame species have received little attention in terms of managed lands for their benefit and that of the general public. A recent study by Payne and DeGraaf (1975) showed that close to one-half billion dollars was spent in 1974 alone on bird related items (seed, binoculars, travel, camera equipment, etc.). Birdwatching, nature photography and other passive, nonconsumption activities have been on the increase. Surface-mines can provide valuable wildlife areas for these kinds of activities. The recommendations described in this paper is an attempt to demonstrate the feasibility of such land uses and to establish a philosophy of reclamation planning for wildlife on reclaimed surface coal mines.

SUMMARY

Studies dealing with the wildlife management potential of reclaimed surface-mines are reviewed. Data on bird species utilization of reclaimed surface coal mines were collected in eastern Kentucky (Breathitt County) over a four year period. These data provided the basis for five low cost recommendations for improvement of bird/wildlife habitat. Pre-planning of reclamation itinerary is a major factor for effective habitat improvement.

ACKNOWLEDGEMENTS

Financial support for the research was provided by the University of Kentucky Institute of Mining and Minerals Research, the U.S.D.A. Forest Service, Northeastern Forest Experiment Station, Research Work Unit NE-1605, the Frank M. Chapman Memorial Fund for Ornithology and Lees Jr. College. Falcon Coal Company allowed access to their reclaimed areas and was helpful throughout the study.

The material presented is part of a Ph.D. dissertation submitted to the University of Louisville. I wish to thank Dr. Burt L. Monroe, Jr., for his guidance and Dr. Thane S. Robinson for reading and commenting on the manuscript.

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Mitigation and Research Needs for Wildlife on Western Surface Mined Lands[1]

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Abstract.--Wildlife mitigation strategy and research needs for western mined lands are discussed and related to the new Federal surface mine law. Particular reference is made to the need for developing best technology available for minimizing losses to wildlife resources. Preliminary results of studies to determine reclamation and mitigation potential for breeding golden eagles (Aquila chrysaetos) are presented as an example of the problems in developing wildlife mitigation practices.

INTRODUCTION

Increased pressure to develop large tracts of coal, coupled with recent environmentally-oriented strip-mining legislation, is necessitating greater cooperation between coal developers and wildlife managers. Mining companies, State and Federal agencies, and others are working more closely to develop sound mitigation strategies for wildlife on western coal lands. New initiatives are needed to implement provisions of the Surface Mining Control and Reclamation Act of 1977. Under this Act, the development and use of "best technology currently available" (BTCA) to minimize mining impacts to fish and wildlife and to enhance these resources where possible is mandated. We are presenting some of our views regarding mining/wildlife controversies using information gained from experiences with conflicts between mining activities and nesting golden eagles.

NEW INITIATIVES

Passage of the Surface Mining Control and Reclamation Act has provided environmental advocates with an opportunity to make great progress toward the preservation and enhancement of fish and wildlife resources. Final regulations of this Act, recently published by the Office of Surface Mining, provide that mine operators must utilize BTCA in all phases of surface mining and reclamation, regardless of the proposed post-mining land use. These regulations will require mine operators to seek guidance from State and Federal agencies in preparation of: (1) environmental assessments and baseline studies, (2) fish and wildlife mitigation plans, (3) post-mining land use, and (4) reclamation plans. In the days ahead many government and private biologists will be asked to provide input into the development of baseline studies and environmental assessments for proposed surface mines. Such studies and assessments must be backed by appropriate research in order to devise suitable mitigation measures for wildlife on western mined lands.

MITIGATION OPPORTUNITIES AND BTCA

Historically, environmentalists have been largely concerned with the preservation of natural areas while less effort has been directed toward the development of mitigation alternatives. It is much easier in practice to set aside areas as "off limits" than to work out mutually compatible mitigation measures. New regulations now make it necessary to identify areas of critical wildlife importance as "lands unsuitable for mining" (Stewart 1978). This would occur in the early phases of the coal leasing process and would incorporate the preservationists' ideology. Realistically, however, few lands could be designated as unsuitable solely on the basis of wildlife values. Therefore, attempts must still be made to accommodate mining activities and wildlife needs. It is after minable lands are identified and during the mine development period that we must learn to couple modern technology with sound ecological principles if we are to provide the best mitigation for fish and wildlife. This is a difficult task.

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In working with mining companies for the past several years, we have become extremely optimistic about possibilities for fish and wildlife protection and enhancement. There are several reasons for this optimism which is based on: (1) a willingness of mining companies to cooperate; (2) a lead time up to 10 or more years from early planning until actual operations begin, providing adequate time to assess important wildlife needs and to develop management options; (3) only part of a surface mine is disturbed at a time, making on-site comparisons of effects possible; (4) mining can, depending on the situation, be flexible in scheduling, allowing for on-site manipulations; (5) economic costs of wildlife reclamation measures are usually lower than costs associated with other types of reclamation; and (6) mining and reclamation can occur simultaneously over a long period of time. As procedures are refined, changes in reclamation practices can be made.

Because mining activity is preceded by lengthy planning periods, biologists have opportunities to develop innovative mitigation technologies. Provisions of the surface mining act require that mine operators use BTCA for wildlife reclamation and enhancement. But what is BTCA and how is it developed? As yet, various BTCA measures are unwritten, poorly defined and untested. There is a great need to retrieve available information about fish and wildlife mitigation and to prepare an organized body of knowledge. But existing information alone will not provide suitable answers to mitigation problems. More in-depth research on factors that regulate populations of economically or aesthetically important wildlife species is needed. To obtain an idea of how and to what extent species will be impacted by large-scale developments and to devise adequate measures to mitigate such impacts will require intensive studies of animal habitat dependence, food requirements, movements, and behavior.

Many nontraditional approaches to wildlife mitigation and enhancement have been developing on mine sites. We know that some simple manipulations of drainage patterns and topography can provide significant benefits to wildlife. Yet wildlife mitigation can be an extremely complex matter and may vary between geographic regions and even between adjoining mines. In addition, certain provisions of the Surface Mining Control and Reclamation Act, intended for environmental protection, have limited our ability to provide BTCA for wildlife. The resolution of conflicts within the Act will require much effort on the part of wildlife advocates. Certainly, the prohibited use of highwall sections as a mitigation and reclamation option for raptors must be overcome. Therefore, the application of mitigation principles may be difficult to achieve without considerable site-specific tailoring and without full realization of legal restrictions. We would like to present our experiences in the research and development of mitigation measures for golden eagles as an example of the complex nature of potential impact problems.

RESEARCH AND MITIGATION FOR GOLDEN EAGLES

Golden eagles, their nests, eggs and young are strictly protected under provisions of the Bald Eagle Protection Act (16 U.S.C. 668a-d). In the Northern Great Plains, conflicts between surface mining and breeding pairs of golden eagles are becoming more common as mine developments expand. To date, over 25 cases of potential and real conflict between surface mines and nesting eagles have been encountered by personnel from the Region 6 Office of the Fish and Wildlife Service and the Sheridan Field Station of the Denver Wildlife Research Center. Efforts to protect nesting eagles in a somewhat traditional manner are now being proposed through implementation of "lands unsuitable for mining criteria" (Stewart 1978). Under these criteria, buffer zones, originally set at one-quarter mile radius, would be placed around the active nests, suspected foraging areas, and important perch sites of golden eagles. Current studies on the effects of coal development on nesting golden eagles have provided some interesting insights into the potential effectiveness of buffer zones, as well as other mitigation possibilities.

With background information on important use areas for test pairs of eagles and a knowledge of mine plans, we have an excellent opportunity to examine or to speculate on the effects of mining disturbances on eagles. Two male and three female individuals from five pairs of golden eagles nesting on or adjacent to newly operational and proposed mine sites were captured, radio-instrumented, and intensively monitored during the 1978 breeding season. Preliminary data indicated that where evenly distributed nesting habitats occur, golden eagles occupy conterminous and mutually exclusive breeding territories. Territories ranged in size from 10.2 to 21.1 square miles with nest sites of each pair located on or close to the periphery of territory boundaries. Data gathered on two pairs of eagles for a year prior to the construction of two mines will continue to be collected as mine developments progress. Within the territories of the other three pairs, mining activity has yet to begin.

By placing buffer zones around the known active nests of each of the five pairs, different levels of protection could be expected. In only one case, that of the eagles we shall call pair "A," could we say that a nest site buffer zone would provide necessary protection from mine disturbances. In this case, a proposed haul road would be constructed approximately 200 yards away from the nest of pair "A" and could threaten the use of the only available nesting habitat within their territory. In contrast with pair "A," nesting habitats are abundant within the territories of two other pairs (arbitrarily labeled "B" and "C") and alternate nests already exist in locations that would be secure from proposed mining activities. Although mining may occur very close to the most recently active nests in these cases, it would be limited to small and little used portions of the eagles' overall territories. Even if the proposed mines destroyed their present nests, we believe that these pairs would simply shift to alternate nests or construct new ones.

Our greatest concern over the application of buffer zones as a mitigation option is represented by the cases of eagle pairs "D" and "E." The active nest sites of each pair are located over one-half mile from the nearest mine activity and, hence, are relatively secure from proposed mine developments. However, scheduled mines would destroy key use areas for both pairs of eagles. Mine developments would overlay a large prairie dog (Cynomys ludovicianus) town that provides a substantial portion of prey for pair "D." (Time-lapse photographs of the nest contents of pair "D" revealed that prairie dogs constituted from 50.0 to 61.7 percent of the prey killed during sampled periods of their nesting seasons in 1976 and 1977.) Although the immediate area around the nest site of pair "E" will not be disturbed, mine developments will destroy a greater proportion of these eagles' territory than will occur with any of the other study pairs. A series of hills and rocky outcrops representing a sizeable (ca. 2.0 square miles) and heavily utilized portion of the territory of pair "E" will be removed by mining. Casual monitoring of this pair in the spring and early summer of 1979 suggests that current mining activities have already forced these eagles to use peripheral regions of their territory.

As may be seen by circumstances surrounding the potential impacts to four of the above pairs, the across-the-board application of buffer zones must be questioned. In these cases, buffer zones may unnecessarily close lands otherwise suitable for mining or, at the other extreme, would fail to adequately protect certain critical portions of an eagle's territory. Favored perching and foraging areas are perhaps as important to the integrity of an eagle's territory as the nest itself and though present buffer zone criteria call for inclusion of such areas they are usually quite difficult to identify without in-depth investigation. In situations as described for eagle pair "E," it is hypothesized that impacts taking place on lands almost 2 miles distant from their nest would pose a more serious threat than for cases such as "B" and "C" where mining could destroy nests, but where actual disturbances would be limited to restricted portions of overall breeding territories.

Although much of the above discussion is based on preliminary data, it is clear that a variety of factors must be considered in order to mitigate (minimize) impacts to breeding golden eagles. The level, proximity, and exposure of disturbances to nests or other use areas are important considerations. Nesting habitat availability and the existence of adjacent breeding pairs will also affect impact severity and mitigation possibilities. It seems only logical, therefore, that mine impacts to nesting eagles should be assessed on a case-by-case basis. Likewise, the merits and use of management or mitigation practices such as establishment of buffer zones, mine activity scheduling, manipulation of nest sites, etc., should be evaluated for each conflict situation.

There are further mitigation possibilities that may help curb negative mining effects to certain pairs of nesting golden eagles other than buffer zones. We are examining ways to manipulate nest site use in an attempt to shift nesting eagles from areas of high disturbance to more secure ones. One such attempt has met with partial success. In 1977, a pair of golden eagles constructed a nest in a highwall on an active mine near Hanna, Wyoming. Although eggs were laid, excessive disturbances caused the eagles to abandon the nest during early incubation. Approximately 2 weeks later the nest was artificially reconstructed on a natural cliff about one-half mile away. The new location, carefully chosen for security from future developments, was positioned on a rock shelf and refurbished with prey remains, whitewash, and nest lining material to simulate recent nesting activity. In 1979, an incubating eagle was observed by mine biologists on the new nest for a period of almost 3 weeks. Although the nest was later abandoned and no absolute signs of a breeding attempt were found, the interest in the site by golden eagles was apparent, and we are optimistic that the reconstructed nest will be adopted in the near future.

We are quite confident that nest site manipulation measures will work and hope to test a variety of techniques in upcoming years. Paternal instincts in golden eagles appear to be quite strong and may work to our advantage in altering nest site use. However, as presented in above discussions, the successful application of these and any other mitigation options depends, in large part, on the extent of impacts throughout an eagle's territory. While there may be cases of impact with no practical solutions, we feel that there are many mitigation alternatives that could prevent most losses of breeding eagle territories through development activities.

CONCLUSIONS

The opportunities to make significant gains for the protection and enhancement of wildlife on surface mined lands are provided under the framework of environmental and mining laws. We have attempted to demonstrate a need for further research and development of wildlife mitigation measures using examples of problems we have encountered with nesting golden eagles. Although many reclamation and mitigation practices that benefit wildlife are known, there are many complex questions that will take a great deal of time and effort to answer. Contradictory provisions of the Surface Mining Control and Reclamation Act severely limit our ability to mitigate wildlife losses by prohibiting certain types of reclamation techniques. These problems must be overcome. The resolution of such wildlife reclamation/mitigation problems will require that wildlife managers recognize future research needs and engage in the development of mitigation strategies. Continued cooperation with mining industries and regulatory interests will be necessary to work out mutually acceptable land use practices that address wildlife protection and enhancement concerns. Current challenges for wildlife mitigation, reclamation and enhancement must be met in order to ensure future availability of wildlife habitats on surface mined lands.

ACKNOWLEDGMENTS

We wish to express our appreciation for the support of Peter Kiewit Sons' Company and Northern Energy Resources Company in making our studies of potential mining impact on nesting golden eagles possible.

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Reclamation of Abandoned Mine Lands and Fish and Wildlife Mitigation Needs[1]

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Abstract.--The Surface Mining Control and Reclamation Act of 1977 has provided a funded program for reclaiming the nation's abandoned coal-mine lands. This paper reviews methods of inventorying such lands and discusses criteria and planning strategies needed to ensure that fish and wildlife values are given consideration in development and implementation of reclamation plans. Habitat evaluation methods are briefly discussed.

INTRODUCTION

One of the major achievments of the Surface Mining Control and Reclamation Act (SMCRA) of 1977 (P.L. 95-87, the Act; U. S. Congress 1977) was the enactment of provisions for a funded program to reclaim abandoned coal-mine lands (Title IV, P.L. 95-87), estimated to be $\approx 4.45 \times 10^5$ ha (1.1×10^6 A) in the United States (Holmberg 1978). Abandoned mine lands are defined by the Act as unreclaimed coal-mine lands that existed prior to 3 August 1977 and for which legal reclamation responsibility does not exist. The Act authorizes Federal, State, Indian, and rural lands reclamation programs. The Secretary of the Department of the Interior (DOI) is charged with administering all of the programs except the Rural Abandoned Mine Program (RAMP) which is administered by the U. S. Department of Agriculture (USDA) through the Soil Conservation Service (SCS). Both DOI (1978) and USDA (1978a) have published their final program rules and regulations.

Funding for the programs is derived from taxes of 35¢/ton on surface-mined coal, 15¢/ton on underground-mined coal, and 10¢/ton on lignite. Half of the money goes directly to the states or Indian-lands program and the remainder is allocated to farmers and small land owners to restore affected lands and to provide technical assistance and administration. The Act establishes the following priorities for funding (high to low): (1) protection of public health, safety, general welfare, and property from any extreme danger caused by past coal mining; (2) protection of public health, safety, and general welfare from adverse effects other than those classified as extreme danger; (3) restoration of the environment and ecosystems previously degraded; (4) research and demonstration projects for development of reclamation and environmental control strategies; (5) protection, repair, replacement, construction, or enhancement of public facilities; and (6) development of publicly owned land adversely affected by past coal mining.

Planning for reclamation of abandoned coal lands requires knowledge of their location, extent, and site-by-site condition. Few states have inventoried their abandoned surface-mined lands, and information on the surface conditions of thousands of abandoned underground-mine sites is poorly documented or unknown. Using aerial photography combined with site inspections, Illinois, Ohio, and Tennessee have conducted rather comprehensive inventories of their abandoned surface-mined lands (Jewell and Haynes 1973, Klimstra and Terpening 1974, Haynes and Klimstra 1975a, State of Ohio 1974, Kaiser

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[1] Paper presented at the Mitigation Symposium Proceedings, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

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1978, TVA and Tenn. Dept. Cons. 1975). Illinois has also completed a detailed study of its abandoned underground-mine sites (Nawrot et al. 1977a, 1977b; Nawrot and Klimstra 1977) and using small scale color-infared aerial photography, Indiana has inventoried its coal refuse sites (Wobber et al. 1975). These inventories were developed mainly to identify and describe problem areas needing major reclamation effort and were not designed to address fish and wildlife needs. Recreational potential of abandoned surface-mined lands have been evaluated in Illinois and Missouri (Roseberry 1963, Ford 1975, Haynes and Klimstra 1975a).

These referenced inventories have demonstrated the diversity of conditions associated with abandoned coal-mine lands. For example, in Illinois about 10% (7,152 ha or 17,700 A) of the surface-mined lands and about 17% (508 sites totaling 2024 ha or 5000 A) of the underground mine sites inventoried were classified as problem areas needing immediate reclamation (Haynes and Klimstra 1975a, 1975b, Nawrot et al. 1977a, 1977b). In Ohio and Tennessee approximately 49% (72,486 ha or 180,000 A) and 43% (6475 ha or 16,000 A), respectively, were identified as needing major reclamation based on such criteria as presence of hazardous mine openings, highwalls, landslide areas, barren and toxic spoilbanks and refuse materials, toxic waters, and abandoned roads, structures, and other debris (State of Ohio 1974, TVA and Tenn. Dept. Cons. 1975). If these lands do not clearly fall under Priority 1 or 2 status, they will likely be classified as Priority 3. Mitigation of the environmental problems associated with these lands should benefit many species of fish and wildlife.

Past inventories have also shown that many abandoned lands have become revegetated through natural succession, or sometimes through planned reclamation. Many of these lands are in need of only minor, if any, additional reclamation or development. They include managed and unmanaged forests, lakes and small ponds, recreation areas, pastures and forage land, and other fish and wildlife habitats on both graded and ungraded lands. Some of these lands may fit into Priority 3, but most probably should be classified at lower funding categories. Plans for any further reclamation or development of such lands must be carefully evaluated to prevent significant negative impacts to the fish and wildlife species that currently use these lands. For example, over the past 40 years numerous research studies have reported the existing or potential value of abandoned coal-mined lands for fish and wildlife habitat (e.g., Yeager 1941, 1942; Bell 1956; Brewer 1958; Klimstra 1959; Verts 1959; Myers and Klimstra 1963; Karr 1968; Riley 1963, 1975; Haynes and Klimstra 1975a; Lyle et al. 1976; Ashby et al. 1978; Chapman et al. 1978; Kimmel and Samuel 1978; Riley and Brown 1978). Other studies have shown that one can reasonably predict the amount of time needed to reach a certain degree of ecosystem recovery if highly toxic (e.g., pH < 4.0) systems are excluded from consideration (Campbell et al. 1965, Carrel et al. 1977, DeMott 1978, Vaughan et al. 1978). For example, Vaughan et al. (1978) have shown that alkaline drainage systems in eastern Tennessee disturbed by contour surface mining could recover to original or near predisturbance levels over a period of 20 to 24 years (i.e., population size, number of taxa, and species diversity). Recovery of fish populations were shown to occur in only those disturbed streams where migration of fish was possible from connecting undisturbed streams (i.e., refuges).

Regulatory authorities should be aware of the potential value of abandoned lands for mitigation and enhancement of fish and wildlife habitat even when this use is not the primary one. Criteria and guidelines should be developed not only to correct problem situations, but also to incorporate both existing and planned fish and wildlife habitats into future land-use and reclamation plans. One suggested approach for accomplishing this task is discussed below.

RECLAMATION OF ABANDONED MINE LANDS: PLANNING FOR FISH AND WILDLIFE

Inventory and Other Supporting Data Bases

As depicted in figure 1, the first step in planning for the reclamation of abandoned lands is to develop a comprehensive and descriptive data base of all sites and to classify these sites into the priorities established by SMCRA. In response to this need, the Office of Surface Mining Reclamation and Enforcement (OSM) within DOI has contracted the Oak Ridge National Laboratory to assist them in developing a national inventory of abandoned mines and related problems. The project includes four phases: (1) Create an initial inventory and design a final inventory system with computer storage and retrieval capabilities, using existing maps, photographs, and previous inventory data bases. (2) Develop a computerized system for storage and retrieval of spatial data. (3) Select study areas for testing and demonstrating the use of remote sensing technology. (4) Complete a national

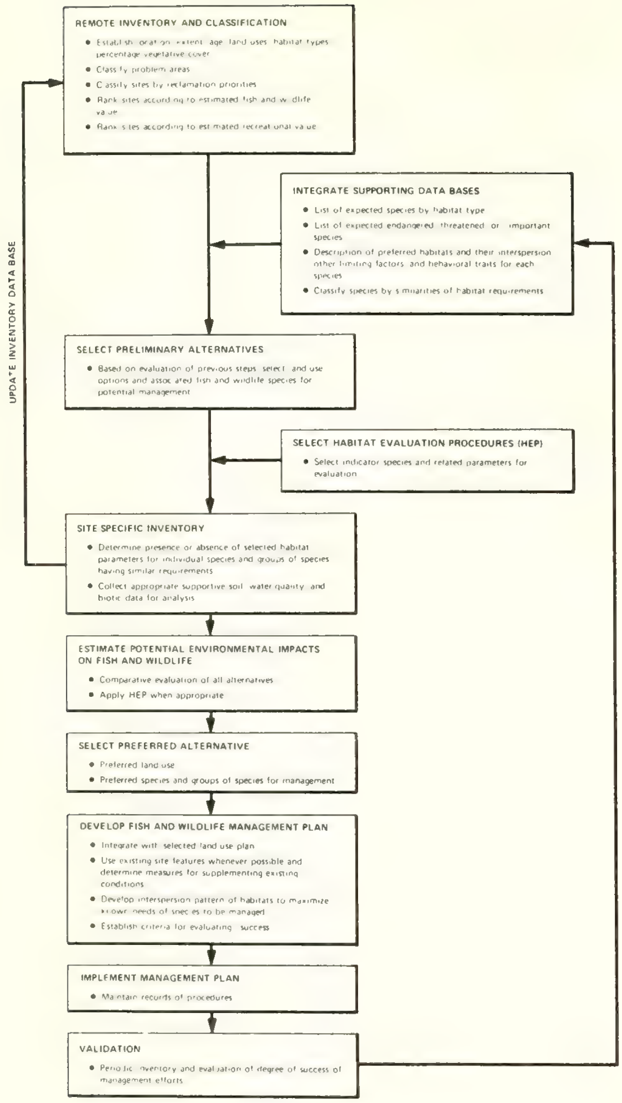
REMOTE INVENTORY AND CLASSIFICATION
• Establish location extent age land uses habitat types percentage vegetative cover
• Classify problem areas
• Classify sites by reclamation priorities
• Rank sites according to estimated fish and wildlife value
• Rank sites according to estimated recreational value
INTEGRATE SUPPORTING DATA BASES
• List of expected species by habitat type
• List of expected endangered threatened or important species
• Description of preferred habitats and their interspersion other limiting factors and behavioral traits for each species
• Classify species by similarities of habitat requirements
UPDATE INVENTORY DATA BASE
SELECT PRELIMINARY ALTERNATIVES
• Based on evaluation of previous steps select and use options and associated fish and wildlife species for potential management
SELECT HABITAT EVALUATION PROCEDURES (HEP)
• Select indicator species and related parameters for evaluation
SITE SPECIFIC INVENTORY
• Determine presence or absence of selected habitat parameters for individual species and groups of species having similar requirements
• Collect appropriate supportive soil water quality and biotic data for analysis
ESTIMATE POTENTIAL ENVIRONMENTAL IMPACTS ON FISH AND WILDLIFE
• Comparative evaluation of all alternatives
• Apply HEP when appropriate
SELECT PREFERRED ALTERNATIVE
• Preferred land use
• Preferred species and groups of species for management
DEVELOP FISH AND WILDLIFE MANAGEMENT PLAN
• Integrate with selected land use plan
• Use existing site features whenever possible and determine measures for supplementing existing conditions
• Develop interspersion pattern of habitats to maximize known needs of species to be managed
• Establish criteria for evaluating success
IMPLEMENT MANAGEMENT PLAN
• Maintain records of procedures
VALIDATION
• Periodic inventory and evaluation of degree of success of management efforts

Figure 1.--Procedures for integrating fish and wildlife considerations into plans for reclamation of abandoned mine lands.

inventory, which will be available for continuing analysis of problems and conditions.

Once the location of abandoned mines is established, much of the information needed by decision makers can be obtained through the use and analysis of aerial photographs and supporting data sets. Evaluation of aerial photographs can provide the extent of barren and poorly vegetated sites and existing habitat types both on and adjacent to the abandoned lands. Further evaluations can allow: (1) tentative classification of sites according to established priorities for funding; (2) ranking of sites for fish and wildlife habitat based on determination of the edges, vegetation type, distribution and cover, and surface water measured directly from aerial photographs (Lines and Perry 1978); and (3) classification of sites according to selected measures of recreational potential (Roseberry 1963, Forrey 1973, Ford 1975, Haynes and Klimstra 1975a).

Existing data sets for fish and wildlife can also be searched to obtain information about species including their behavioral traits, habitat diversity and interspersion needs, and other limiting factors that might occur on abandoned mine lands (fig. 1). To optimize use of such data, it should be computerized and made available to users along with simple user instructions. Otherwise, time consuming searches of the literature will be required to obtain the needed information.

A prime example of this type of system is FAUNA, a computerized faunal information system for use by land managers in land-use decisions affecting fish and wildlife resources (Mason et al. 1979). This work is being directed by the U. S. Fish and Wildlife Service's (USFWS) Eastern Energy and Land Use Team. FAUNA is largely textual with information on species distribution, key habitat factors, food, cover and niche requirements, and management potential for fish, amphibians, reptiles, birds, mammals, and selected aquatic and terrestrial invertebrates (Mason et al. 1979). A major goal of the USFWS is to provide users with such data for regions, ecosystems, and specific habitat types. Progress is being made in achieving this goal but much more work remains to be completed (USFWS 1977, 1978; Patton 1978; Schweitzer et al. 1978).

Habitat evaluation procedures (HEP) presently being developed and tested by the USFWS (Schamberger and Farmer 1978), may be useful for planning the reclamation of abandoned lands (fig. 1). These procedures were designed to provide baseline information on selected indicator species (singly or in associations) and their habitat needs for subsequent use in evaluating and quantifying environmental impacts on these species from proposed projects and land-management schemes. Their use assumes that the quality of various ecological communities can be objectively characterized and quantified by determining the degree to which known life requisites of indicator species are provided. Thus, use of HEP is restricted to those species whose habitat requirements are well documented in the literature. Application of HEP leads to determination of a habitat suitability index (based on assessment of physical and biological parameters), a habitat quality index (total of the suitability indices for all indicator species), and a habitat value (product of the area of habitat and the habitat quality index) (Flood et al. 1977, Raleigh 1978, Schamberger and Farmer 1978, USFWS 1979). If HEP are to be used in evaluating abandoned mine lands, indicator species and their physical and biological limiting factors must be identified so that these factors can be sampled during subsequent site-specific inventories. The USFWS should plan to provide guidance and assistance to potential users if they intend for HEP to be used in the evaluation of reclamations for abandoned lands.

Careful evaluation of existing features of abandoned lands, as determined remotely and prior to site-specific inventories, will provide information needed by planners to tentatively select several reclamation options together with important factors needed for management of fish and wildlife. Subsequent site-specific inventories (fig. 1) should then be designed to assess the presence or absence, quality, and quantity of these factors. Site inventories may also lead to reclassification of funding priorities based on additional information obtained, e.g., hazardous mine openings, acid mine drainage, or other conditions not previously identified by remote evaluations.

Determining Environmental Impacts on Fish and Wildlife and Selection of Preferred Reclamation Options

Site-specific inventories that are properly designed and conducted to measure the critical or limiting factors should provide the information needed by planners to evaluate impacts of proposed reclamation plans. This should lead to the selection of preferred reclamation and land-use alternatives resulting in the correction of environmental problems and optimization of fish and wildlife values (fig. 1). The HEP discussed earlier (Schamberger and Farmer 1978, USFWS 1979) can be used to quantify impacts on selected indicator species due to proposed reclamation activities. For those species or groups of species possessing similar habitat requirements which are not or cannot be evaluated by HEP, a perturbation matrix may be utilized (States et al. 1978). This type of matrix provides a qualitative assessment of potential impacts by comparing proposed reclamation activities with expected damage or destruction of habitats and their biota.

Development, Implementation, and Validation of Fish and Wildlife Management Plans

Fish and wildlife management plans should always be integrated with the final reclamation strategy and corresponding land use (fig. 1). The basic guiding philosophy should be to utilize as many of the existing features of the abandoned sites as possible, while using supplemental plantings, water sources, and other measures as needed to enhance food, cover, water, and spatial needs for the managed species. It is also important to remember that the abandoned sites represent only one or more components of a larger management unit that includes the land uses and habitats adjacent to them.

Two other somewhat conflicting management approaches must be considered. One focuses on increasing the total number of species that can use an area by increasing habitat diversity, while the other must recognize the special needs of any endangered, threatened, rare, or otherwise important species that may be adversely affected by the intended management strategies. Therefore, planners must go a step beyond simply identifying important habitat types and incorporating them into management plans. The optimum percentage of each habitat type and the spatial design of habitats (interspersion) which provide the most benefits to single or groups of species must be considered; this should include provision of movement corridors between one habitat type and another.

Numerous helpful documents which discuss in detail the above management concepts are available to planners (e.g., Leopold 1933, Lagler 1956, Giles 1971, Burger 1973, Leedy et al. 1978, Rafaill and Vogel 1978, Raleigh 1978, Puglisi and Hassinger 1978). In addition, the expertise of experienced biologists should be employed at all stages of the project planning, review, and implementation.

We believe that it is extremely important for planners to develop methods and criteria for validating the success or deficiencies of the implemented management plans. This requires diligent descriptive record keeping of the project design and activities. It should be continued with measurement and evaluation of previously selected criteria of success at periodic intervals following implementation of plans. Plans should provide for the integration of such data into existing data sets as quickly as possible to assist in development of future management plans (fig. 1). Also, in later years of abandoned mine lands programs, such data may be needed to justify additional funding and continuation of programs.

CONCLUSIONS

We believe that successful integration of fish and wildlife values is possible at all levels of reclamation of abandoned lands. Programs for reclaiming these lands should greatly benefit many species of fish and wildlife through the correction of adverse conditions associated with past coal mining. However, we expect that the degree of significant positive benefit to fish and wildlife through reclamation or development efforts will decrease for some proposed projects with low funding priority (i.e., SMCRA, some Priority 3 or lower priorities), and there could be significant adverse effects on fish and wildlife.

Our involvement with the Rural Abandoned Mine Program (RAMP) in Tennessee through Committee review of applications for reclamation funding has impressed upon us the diversity of opinions regarding reclamation priority classification and proposed reclamation and management alternatives. For each proposed project reviewed by the RAMP Committee, numerous alternatives (e.g., whether or not highwalls should be eliminated or affected lands returned to their approximate original contour, sources of topsoil or other material for amending toxic conditions, species of vegetation to be established) were apparent, all of which may affect fish and wildlife populations. Such differences of opinion have lead us to believe that an environmental impact assessment (EIA) should be prepared for every proposed reclamation project, and in those cases where an EIA reveals reasonable prediction of significant negative impacts to the environment, an environmental impact statement (EIS) should also be prepared as dictated by the National Environmental Policy Act (NEPA). Many of the recommendations and procedures presented in this paper for coordinating fish and wildlife management plans into other land-use and reclamation plans can be an important part of preparation of environmental impact documents.

Our involvement with RAMP has also shown us that this Program will use EIA's and EIS's within the framework of recent Council on Environmental Quality (CEQ) regulations and guidelines for implementing NEPA (CEQ 1979; USDA 1978a, 1978b). Although we expect the OSM to clarify further their position with regard to the CEQ regulations, their compliance policies for using EIA's and EIS's in their abandoned mine programs have not yet, to our knowledge, been clearly defined (DOI 1978). We strongly urge fish and wildlife biologists to assume an active role in these evolving programs to ensure the mitigation, enhancement, and protection of fish and wildlife in all reclamation and development efforts.

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Wildlife Mitigative Measures for Oil and Gas Activity in Alberta[1]

C. W. Bruce Stubbs and Brent J. Markham[2]

Abstract.--Mitigative measures for oil and gas activity are based on two impacts: 1) the activity itself and 2) the resultant increase in public access. Good relationships between government and industry and between government agencies must exist to institute these measures.

INTRODUCTION

The Alberta Fish and Wildlife Division has the mandate to manage and manipulate wildlife populations and their habitats within the province. This paper will deal with one land use - oil and gas exploration and development - and the manner it is dealt with to fulfill that mandate.

The Fish and Wildlife Division participates in complex intra-governmental referral systems. These systems are capable of seeking reactions, conditions and comments from different Government agencies to proposals for land use. It is through these referral systems that the Division recommends for implementation those conditions we feel protect or benefit wildlife resources vis á vis land uses.

The province of Alberta is some 660,450 sq. km in size. Of this approximately 63% is Crown land (provincial public land) and it is on this land base that the Division places its greatest emphasis in managing land uses. This emphasis reached a climax in July of 1977 when the Government of Alberta released "A Policy for Resource Management of the Eastern Slopes". This policy outlined wildlife as being one of the most important resources of this part of the province and designated a number of Zones (catagorized as Zone 2) to be "critical wildlife". The policy further stated that, "The Critical Wildlife Zone consists of ranges or habitats such as key winter range, migration routes and calving areas that are essential to the survival of specific wildlife populations." and that "Dispositions and land uses within the Critical Wildlife Zone must be compatible with wildlife management objectives." The Fish and Wildlife Division is committed to maximizing wildlife production in the "Critical Wildlife Zone" and as such only land uses compatible with this objective will be permitted. It was clear then that the Fish and Wildlife Division had to develop measures that would accommodate other land uses yet maintain its responsibility to Government policy.

Oil and gas activity has increased dramatically in recent years in the Alberta Eastern Slopes and a significant discovery was confirm during the fall of 1977. This discovery led to some of the most intensive exploration on the continent and created problems for wildlife resources. Because the area of intensive activity involved several Critical Wildlife zones it was necessary to develop a number of innovative approaches and conditions to mitigate the impact on wildlife.

The Division is involved in oil and gas development in Alberta from the sale of the Crown mineral rights to field development. Th paper addresses four different levels of invol ment; seismic, mineral sales, exploratory dril ing and field development. Each catagory is described as to the mitigative measures propos by the Division, their rationale and general comments on implementation and acceptance. No all of the following measures are conditions o approval, some are achieved by agreement direc between the Division and the company involved.

SEISMIC

All surface seismic activity in Alberta must receive Government approval. It is at this approval state that mitigative measures for wildlife are instituted. The impact of a seismic program on wildlife can be separated into two functions: 1) the impact of the activity and 2) the resultant impact of access

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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Activity

ming: In many situations seismic activity ll conflict with wildlife utilization of y habitats. The degree of impact depends on the intensity of the activity, i.e. e number of concurrent programs, the number seismic lines, the length of time in the y habitat, etc. The timing restriction ll change with the habitat involved. In berta, the following applies:

1. Ungulate winter range - no activity between December 1 to May 1 this may be extended to reduced for any time of year. To protect lambing or calving grounds activity should not take place until after July 1. To protect bighorn sheep rutting areas that are traditional and site specific, fall activity should be restricted between October 15 and December 31.

2. General - waterfowl nesting areas and upland bird display grounds are protected by short (approximately 2 months) timing restrictions in the early spring. Special attention is given to colonial nesters and species such as trumpeter swans.

mpsites: Seismic programs in remote areas e centered at base camps, the placement and sociated activity of these camps can have gative impacts on wildlife. To reduce ese impacts the following conditions are used.

1. Campsites should not be located on open meadows used by ungulates. They are to be placed in heavy coniferous cover and buffered from utilized natural openings by at least 100 m (fig. 1).

gure 1.--Poor site selection has resulted in this seismic campsite being located on a river flat that usually winters 30-50 elk.

2. Company personnel in the camp should not be permitted to have firearms in their possession, nor are they permitted to use ATV's, motor bikes, or snowmobiles for pleasure during off hours. The company accomplishes this by making it understood as a condition of employment.

3. In areas where problem wildlife is expected (particularly black and grizzly bears) all garbage must be removed daily, burned and buried at a site not less than one mile from the campsite.

These conditions for campsites are intended to reduce negative impact by decreasing the harassment factor and controlling the problem before it starts.

Helicopters: On many seismic programs, particularly portable operations, helicopters are used extensively to ferry both men and equipment. Helicopters have a very distressing effect on big game and therefore this activity should be kept to a minimum.

1. Helicopters should be kept to a specific lane of travel and there should be no deviations for "sight-seeing" tours.

2. In alpine areas concentrating bighorn sheep helicopters should not land or fly above the treeline.

3. When dealing with mountain goats, helicopter activity should be kept as close to the valley floor as possible. This will keep them below the goats and provide escape security. This is particularly important in the early spring when the kids are a few weeks old and still developing their physical capabilities of dealing with rapid escape.

These conditions will reduce the degree of harassment on wild ungulates which is important during times of the year when the energy balance is critical and/or when young of the year may be placed under undue stress.

Realignment: Some proposed lines may run directly to or through habitat that may be destroyed or cause increased access that cannot be controlled. Examples could be specific nesting sites, or onto an ungulate wintering slope. In such cases we may request the original line be adjusted to accommodate these sites. This is done before approval is given.

In some key wildlife areas, the intensity of proposed seismic activity threatens habitat integrity through habitat destruction.

1. Conventional lines (approximately 6 m wide) within 10° variance should not be closer than (one-half km) of each other or existing lines (existing lines defined as being those lines where regeneration does not exceed 2 m).

2. Portable lines (1-3 m wide) within 10° variance should not be closer than one-quarter km to each other.

These conditions are used in areas of very intense activity and are solely for the protection of habitat.

Access

Increased public access to remote key wildlife areas of concern to wildlife managers in Alberta. This access is causing declines in existing populations (particularly ungulates) and is inhibiting populations from recuperating to take advantage of naturally developing habitat (eg. timber cut blocks, seismic lines, etc). The problem is complex, dealing with increased licensed hunting opportunities, increased year-round native hunting and increased harassment by recreationists (snowmobiles, trail bikes, 4 x 4's, ATV's, hikers, etc.) To control this increased access we have instituted measures that reduce the amount of easy access and at the same time provide security for animals to use available habitat.

1. Where a conventional line intersects a point of access (i.e. a road, trail, another seismic line, etc.) the line is to be dog-legged and the dog-leg is to be closed by piling debris along its length. This is accomplished by permitting only a surveyors line through the dog-leg (fig. 2).

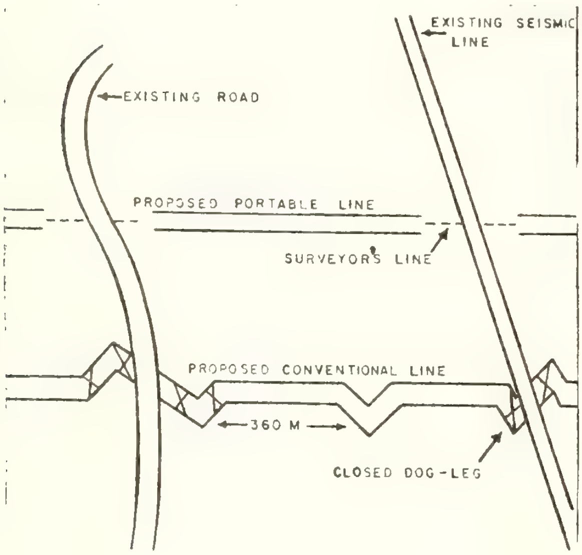

Figure 2. This diagram illustrates the mitigative measures implemented for conventional and portable seismic activity in key wildlife areas.

MINERAL SALES

Eighty-five percent of the mineral rights in the province are owned by the Crown in the Right of Alberta (public ownership). These rights are leased to the industry under regulations by selling them usually through public notice for bidding. The Fish and Wildlife Division is part of the Government system that reviews proposed sales before they occur. The purpose is to define those areas which may be of potential conflict and recommend mitigative measures. The timing of sales notices has also been addressed so that measures are now taken to ensure that the time of the sales in certain areas does not conflict with existing time restrictions to protect wildlife resources. This deals with the problem of the "rush" by the industry to collect and assess exploration (seismic) data to determine the company's position on bidding in the short time between the sales notice and the sales date. In Alberta, the following measures have been taken in specific areas critical to wildl

1. Mineral sales notices have been adjus so as not to conflict with wintering timing restrictions on seismic activity. This is done through information letters to the indu try outlining these areas and informing them of restrictions.

2. Addenda are attached to sales that occur within key wildlife areas. These addenda inform the industry, before they bid that there may be certain restrictions place on activity and identifies a person within the Fish and Wildlife Division to be contact for further information.

3. In situations where activity will not be permitted, the addenda indicates no surface access or the area involved is recommen not to be sold.

4. A procedures of "advanced booking" is instituted in areas where the exploration well is greater than 3,000 meters deep and interest is expressed on an adjacent are of vacant Crown land. This reduces the timi pressure on the industry which would lead to conflicts with surface timing restrictions.

EXPLORATORY DRILLING

Drilling for oil and gas creates much the same problems to wildlife as seismic in that the impact can be separated into two functions 1) the activity itself and 2) the subsequent increase in access. This activity generally requires the building of high quality roads fo the movement of heavy equipment and personnel to the drilling site. It is the lay-out, cont of access, and reclamation procedures for bandonment of these roads that is the key o mitigation for wildlife. For the wildlife anager, the drilling and future development f an oil and/or gas field requires a great eal of imagination to institute measures hat will at least maintain wildlife populations.

Activity

iming: The timing restriction placed on drilling follow much the same period as that for eismic (no activity between December 1 to May on big game winter ranges, etc., see SEISMIC, ctivity). The rationale is also the same--to educe the harassment factor on wildlife during nose times of the year that are especially ritical to their survival.

nstruction Site:

1. The access road should be aligned such that it does not cross key habitats and should be buffered to prevent visual contact by animals using these habitats. For example, the road should not cross open meadows or mineral licks (fig 3). To prevent long lines of sight, roads should be curved every 360 m unless this is already accomplished by natural terrain.

gure 3. This oil access road should have een planned to go around this meadow nd be properly buffered (100 m) so as not o be visible.

2. Campsites, garbage disposal and control of recreational activities by company ersonnel (snowmobiles, etc.) is addressed n the same manner as seismic (see SEISMIC, ctivity).

3. The wellsite location should not be n or near key habitats (wintering slopes, ineral licks, etc.) The wellsite should e buffered by vegetation that eliminates isual contact. A guideline we use is a 00 m buffer.

4. To protect waterfowl nesting habitat, wellsites and roads should not be within 100 m of the high water mark of the waterbody involved. When dealing with trumpeter swans this should be extended to at least 300 m.

Access

Increased public access is accentuated during drilling activity because the new roads are usually of high enough quality to permit normal passenger vehicle traffic. This of course dramatically increased both legal and illegal hunting opportunities, native year-round hunting and year-round recreational opportunities. The result is a quick reduction in ungulate numbers, a slower but more dramatic (in terms of recovery) decrease in species such as grizzly bear and sterilization of potentially good habitat. The object, then, is to control public access.

1. Access roads should be closed with a locked gate and there should be a sign indicating the road is closed to public vehicular traffic for reasons of wildlife protection (fig. 4). If the situation warrants, such as very long drilling periods (eg. 18 months) or where access can be easily (and illegally) gained, then the company is required to have the gate manned on a 24 hour basis to control access.

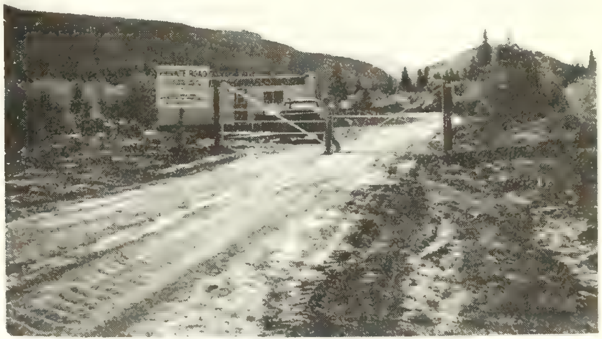

Figure 4. This road was closed with a locked gate and manned 24 hours to protect wildlife resources.

2. Every effort should be made to require companies to use each others or existing access roads (except where these roads are in conflict with wildlife habitat management and are to be removed). This will reduce the amount of access developed.

FIELD DEVELOPMENT

We have now reached the stage of considering how to mitigate full field development in key wildlife habitats (fig. 5). The problem is extremely complex mainly because of the numbers of different companies involved. The following are some guidelines that have been generated and will be implemented. The normal well spacing in Alberta is one every one-quarter section (one-half mile by one-half mile) for an oil field and one every section (one mile by one mile) for gas. As can be appreciated this type of intensive development can be the demise of many species of wildlife considering the fact that each well must have good quality access for maintenance. This complex situation requires a great deal of imagination and long range planning.

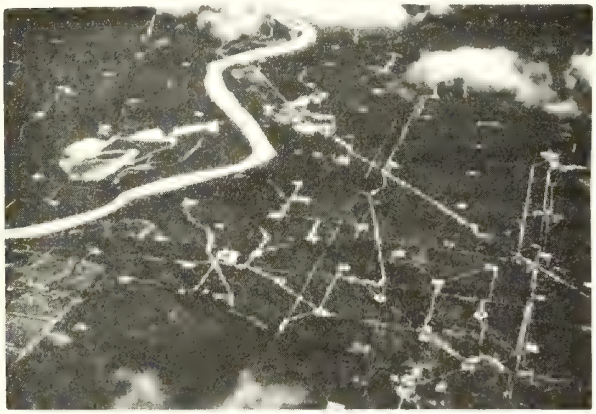

Figure 5. This is an example of a fully developed gas field in an area that historically provided good habitat for big game.

1. Maximum use should be given to existing access. Companies should be requested to "double-up" as much as possible. Existing roads created either during or before exploratory drilling should be closed and reclaimed to vegetation beneficial to wildlife.

2. Pipelines to battery sites and major pipeline rights-of-way should accommodate more than one line to reduce habitat destruction. Pipeline rights-of-way can also be reclaimed to enhance ungulate use. This can be done by planting palatable browse species that can also act as a visual screen on the right-of-way (fig. 6).

3. The significant increase in access may require special regulations to govern hunting (egs. short seasons or special permit draws).

4. It may be necessary to develop main points of access to control general public recreational activity. This is very difficult considering the large size of the fields.

5. There should be intensive habitat development schemes to increase carrying capacity for wildlife. This will attempt to replace habitat lost through road construction and wellsites.

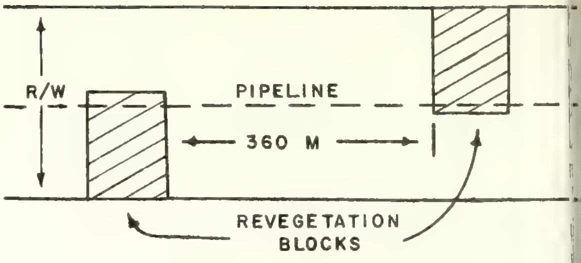

Figure 6. By planting palatable browse spec in staggered blocks, a pipeline right-of-w can provide security and food for wild ungulates.

DISCUSSION AND CONCLUSIONS

Generally the oil and gas industry in Alberta has accepted our mitigative measures and have been very cooperative. Some compan have retained biological staff at our request to monitor programs (particularly seismic). This monitoring is assessed by the Fish and Wildlife Division and gives us an indication of the effectiveness of our mitigative measu a better understanding of impacts and outline new measures that may be instituted. It is important to explain to the industry the need for these measures. This means several meetings between the Division and the industr (collectively and individually). It has mean presentations to industry groups and associations, articles in publications that the indu is acquainted with and information letters from the Government. The industry is extreme competitive and it is important to reach as many as possible as often as possible.

There are several key factors that are involved in the institution of these conditio and guidelines:

1. Any or all of the mitigative measure can be used on any given program. They can be modified, deleted, or added at the discretion of the wildlife manager in the fiel This lends credibility to the measures themselves and allows for changes with varying wildlife species, habitats and the differin natures of the programs.

2. They are dependent upon good liaison between the field wildlife manager and the industry. It is particularly important to deal with company staff who will be supervising the program. If the vice-president is aware of conditions but the "cat-skinner"

s not many of the conditions or guidelines are seless.

3. Another key factor is good intra-overnmental relations. The Alberta Fish and ildlife Division is a recommending body on ost land use issues. We are not legislatively mpowered to issue conditions or guidelines. owever, our mitigative measures are incorpoated under legislative authority granted other overnment agencies.

4. The mitigative measures are in a onstant state of flux. It is important to ontinually update and modify but at the same ime maintain a level of consistency. This s crucial when dealing with the industry hich is constantly aware of each others ituation. Each proposal must be dealt with n its own merits but consideration is also iven to future impacts. For example, it may e permissable to allow one seismic program o operate during January in a particular rea, but the exploration pressure from her companies may be such that the combined tivities will be too much for the wildlife volved. It is, therefore, wiser to restrict l activity giving no one an unfair advantage.

5. There is no doubt that these measures e under continuous questioning as to their legitimacy. It goes without saying that there is not sufficient research information (particularly in Alberta) to fully support our position. However, this is true with most renewable resources dealing with land use issues. It is also true that land use activities are progressing at such a rate as to preclude much of the long term research needed. It behooves wildlife managers to use the information at hand to deal with immediate problems. After all, if the expert in the wildlife field cannot pass judgement on land use impacts and mitigative measures there is no one else who can.

Mitigative measures for wildlife on oil and gas activity is a relatively recent development in Alberta. We have made great strides and are still developing. To date cooperation from industry and within government has been good. We are assessing the impacts of these measures as we go along. Certainly there will be changes but our experience has been that wildlife can be incorporated into most oil and gas activities. Our approach has been that wildlife and its management is no more important than other renewable and non-renewable resource management--but certainly no less.

Coastal Impact Mitigation and OCS-Induced Oil and Gas Development: A Perspective of the Clean Water Act's Section 404 Guidelines[1]

Charles R Terrell[2] and Larry R. Shanks[3]

Abstract.--In recent years the petroleum industry has increased its development effort of oil and gas resources on the nation's Outer Continental Shelf (OCS), while concomitantly there has been a rapid increase in coastal development by the petroleum industry and others. Environments and ecosystems have sustained large alterations, leading to reduced productivity and loss of prime fish and wildlife habitat.

Oil and gas industry projects in need of careful environmental planning and best construction practices include: (1) navigation and access channels; (2) dikes and levees; (3) bulkheads and seawalls; (4) jetties and breakwaters; (5) roads, causeways and bridges; and (6) pipelaying. Construction techniques, employed to reduce environmental impacts, are: (1) dredged material containment; (2) non-structural beachfront management; (3) elevated roads; (4) push-ditch pipelaying in wetlands; and (5) directional drilling.

Proposed projects and activities, covered by S404 of the Clean Water Act of 1977, are any projects or activities involving the discharge of dredged or fill material into waters of the United States, including wetlands. The S404 Guidelines, currently being revised by the U.S. Environmental Protection Agency in conjunction with the U.S. Army Corps of Engineers, allow discharge where it will not cause unacceptable adverse impact on environmentally sensitive areas.

The Guidelines mandate the examination of practical alternatives to the discharge of dredged or fill material. A general evaluation determines the possibility of a chemically polluted sediment. "Guidelines to Minimize Impacts" are incorporated concerning the substrate, water quality, tidal fluctuations, currents, salinity and other characteristics. Particular attention must be given to minimize construction impacts to special aquatic sites, such as sanctuaries, refuges, wetlands, vegetated shallows and coral reefs. Based on the Factual Determinations which are made, the Corps of Engineers must decide if the proposed action is in compliance with the S404 Guidelines, and thus whether or not to issue the permit.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, July 16-20, 1979.

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INTRODUCTION

In recent years the petroleum industry has expanded its Outer Continental Shelf (OCS) development efforts to achieve increased production of oil and gas. Offshore production now accounts for a substantial part of the total domestic output. It is generally acknowledged that offshore production may be as much as 40 to 50 percent of all domestic production within the next 15 to 25 years. (Clark, Zinn & Terrell, 1978). As OCS exploration and production has proceeded, demands have increased for support facilities in the nearshore and onshore areas.

Coastal impacts from oil and gas development affect: (1) open water; (2) barrier beaches, estuaries and shorelines; and (3) wetlands. Each of these has intrinsic ecological properties which must be protected from construction practices, including the discharge of dredged or fill material. In many cases certain design, construction and operational practices can be implemented to reduce or eliminate the environmental degradation.

EFFECTS ON LIVING RESOURCES

Resource and environmental impacts may be severe for the onshore oil and gas facilities associated with offshore development. Concerns relating to fish and wildlife and their habitats are most significant for large, heavy-impact OCS projects, such as exploration, drilling, platform fabrication yards, pipelines, oil refineries,and petrochemical industries. Effects on living resources may arise from decisions made in four distinct phases of OCS projects: location, design, construction, and operation. The following considers only those factors having a major influence on fish and wildlife (Clark & Terrell, 1978).

Location: Waterfront locations of facilities may require dredged and fill material disposal which can lead to adverse environmental effects, such as turbidity, eutrophication, toxicity, oxygen depletion, shoreline alteration, wetlands loss and benthic habitat destruction or degradation. Where facilities are not actually dependent upon a waterfront location, the use of upland areas will avoid many of these problems, and will retain waterfront sites for uses which require that type of access.

Design: The high potential for adverse aquatic impacts of a waterfront location requires that maximum care be taken in facility design. Provisions to protect habitat include maintaining the natural shoreline, minimizing dredging, disposing of dredged material properly, avoiding wetlands, reducing runoff problems, and employing buffer strips. Elevations below the 100-year flood level are generally undesirable for OCS facilities in coastal or floodplain areas.

Construction: During site preparation there can be a number of serious environmental effects, direct and indirect. Provisions to minimize environmental damage include limiting the alteration of aquatic systems, preventing soil erosion, and properly restoring sections altered by construction. Excavation and filling areas near wetlands should be performed in a manner which prevents sediments from entering the wetlands ecosystem.

Operation: Frequent maintenance dredging of access channels may cause serious problems, particularly in the availability of suitable disposal sites. Therefore, location and design are important.

OCS projects, which have the potential for producing impacts to the aquatic ecosystem, are among others:

1. Offshore oil and gas platform projects
2. Pipeline
3. Offshore mooring and tanker terminal projects
4. Onshore service bases
5. Platform fabrication yards
6. Pipe-coating yards
7. Oil storage terminals
8. Refineries and petrochemical plants
9. Gas processing plants
10. Liquefied natural gas plants

The above projects can be divided into individual subprojects (Clark & Terrell, 1978):

1. Navigational improvements
2. Beach stabilization
3. Bulkheads and piers
4. Dikes and levees
5. Artificial watercourses and water bodies
6. Site preparation and development
7. Roadways and bridges
8. Groundwater supply
9. Sewage and stormwater systems
10. Industrial wastewater systems
11. Overland and submerged petroleum transmission systems
12. Solid waste disposal
13. Marine shipment of oil

Activities which lead to disturbances of the environment may trigger a complex sequence of effects. Usually the effect between the disturbance and the impact have more similarity to a web of interrelated events than to a straight chain of events. Often a variety of effects leads directly from a single disturbance. Potentially adverse activities associated with the above projects and subprojects are (Clark & Terrell, 1978):

1. Canal excavation
2. Dredging
3. Excavation and earth moving
4. Fill deposit and removal
5. Land clearing and grading
6. Pipeline construction
7. Oil and gas drilling
8. Paving
9. Pile driving and jetting
10. Dredged material deposition
11. Structure erection
12. Trenching

GUIDELINES FOR SPECIFICATION OF DISPOSAL SITES FOR DREDGED OR FILL MATERIAL

In 1972, Congress passed amendments to the Federal Water Pollution Control Act of 1948. Section 404 of the 1972 Amendments authorized the issuance of permits by the U.S. Army Corps of Engineers for the discharge of dredged or fill material into the waters of the United States. The Corps issues permits for specified disposal sites which are approved through the application of Section 404(b)(1) Guidelines. The Interim Final Guidelines were developed by EPA in conjunction with the Corps and were published in Federal Register on September 5, 1975. They are currently being revised.

In December 1977 Congress made a major overhaul of the Federal Water Pollution Control Act, now known as the Clean Water Act. Section 404 was expanded with EPA receiving responsibility for reviewing and approving State 404 permit programs to operate in lieu of the Corps' permitting responsibility in certain State waters which traditionally have been considered non-navigable. However, the touchstone of the 404 permit process remains compliance with EPA's Section 404(b)(1) Guidelines.

The Congressional amendments specified several applications of the Guidelines: (1) Corps of Engineers' General permits shall be based on the Guidelines; (2) a State desiring to administer its own permit program must apply and assure compliance with the Guidelines; (3) the EPA Administrator can withdraw a State program or prevent a State from issuing a permit for cause, including failure to comply with the Guidelines; (4) an EIS for a Federal construction project, to be exempted under Section 404(r) must include consideration of the Guidelines; and (5) Best Management Practices, prepared under a Section 208(b)(4) areawide regulatory program, must also comply with the Guidelines.

The Guidelines recognize that entire aquatic and wetland ecosystems can be affected by the discharge of dredged or fill material. The concept of critically important sites of the aquatic environment is included in the Guidelines with emphasis on wetlands as a significant component. Also identified are values associated with wetlands and specified methods of preventing or minimizing impacts of the discharge of dredged or fill material into wetlands. The Guidelines present procedures for testing proposed dredged material to predict unacceptable impacts on aquatic organisms.

Practical Alternatives

The S404(b)(1) Guidelines provide for the examination of practical alternatives to the discharge of dredged or fill material into U.S. waters and wetlands. Even when the preliminary evaluation shows that environmental impacts fall within the acceptable range, it remains necessary to examine and consider practical alternatives with less damaging environmental impacts. The Act's S403(c) criteria, on which the Guidelines are statutorily based, include "other possible locations and methods of disposal or recycling of pollutants including land-based alternatives."

The evaluation of practical alternatives must take into account all alternatives which meet the criteria of practicality, which includes consideration of economic, technical, and logistical feasibility. The range of alternatives considered should include: (1) "internal" alternatives, that is, modifications to the activity, such as timing of the discharge, alternate locations at the same general site, mitigating measures, etc.; and (2) "external" alternatives, such as major modifications in the nature of the proposed activity or change in site outside the permit application as submitted.

Generally the least damaging, yet practical alternative should be selected. In the case of discharges of fill material into wetlands, water dependency for the proposed activity should be considered a mandatory condition of compliance except upon the finding that other siting or construction alternatives are not practicable and the proposed project will not cause permanent adverse disruption to beneficial water quality uses of the system.

Testing Procedures

The S404(b)(1) Guidelines mandate an

evaluation and testing procedure. The Guidelines provide for a general evaluation procedure, to eliminate from testing those proposed discharges which have low probability of possessing contamination in harmful amounts. This procedure works through the evaluation of available information and the application of reasonable judgment. Tests are only necessary to demonstrate that a discharge will not produce a significantly adverse effect on the aquatic and wetland ecosystem. In addition, it is possible to avoid all testing if the general evaluation gives a reasonable assurance that contaminants are not present, or if the applicant accepts constraints for the worst probable polluted conditions.

Guidelines to Minimize Impacts

Substrate

The discharge of dredged or fill material can result in changes to the complex physical, chemical and biological characteristics of the bottom substrate. These changes can adversely affect the substrate environment and often are reflected throughout the entire aquatic ecosystem. Adverse impacts can be compounded by the presence of contaminants in the dredged or fill material. Specific methods have been incorporated into the S404(b)(1) Guidelines to minimize impacts to the ecosystem. For the aquatic and wetland environment the following are guidelines to minimize impacts to the substrate.

1. Confining the discharge to the smallest practical deposition zone, so adjacent substrates will be protected.

2. Discharging materials to minimize changes in substrate elevation, thereby preventing modifications of the water mass movements leading to erosion or other adverse impacts.

3. Spreading discharge material in a thin layer over a large area, when mounding material is not appropriate.

4. Selecting discharge methods and disposal sites which have reduced chances for erosion, slumping, or leaching of harmful materials into the surrounding aquatic or wetland areas. Particularly useful methods are the use of containment levees, sediment basins and cover crops to reduce erosion. Clay or synthetically lined containment areas will reduce chemical leaching.

5. Selecting a disposal site which has been previously used or selecting an upland disposal site where it represents an environmentally satisfactory alternative.

6. Capping in-place contaminated material with clean material or selectively discharging the most contaminated material first, so it can be capped with less-contaminated material.

Suspended Particulates

The discharge of dredged or fill material can result in greatly elevated levels of suspended particulates in the water column. High turbidity reduces light penetration, lowering the photosynthetic rate and thus the primary productivity of the aquatic area. Sight-dependent species are impacted through reduced feeding activity, leading to limited growth and lowered resistance to disease. Both biological and chemical content of the suspended material will react with the dissolved oxygen in the water, which may result in oxygen depletion. Toxic metals and organics, and pathogens and viruses sorbed to fine-grained particulates may become biologically available to organisms in the water column. The following are guidelines to minimize impacts from suspended particulates.

1. Using silt screens or other appropriate filtration methods to confine suspended particulates.

2. Making use of currents and circulation patterns to mix, disperse and dilute the discharge.

3. Minimizing water column turbidity by using a submerged diffuser system or by submerging pipeline discharges.

4. Utilizing chemical flocculants to enhance the deposition of suspended particulates in diked disposal areas.

5. Discharging at times of the year which will minimize adverse effects to plants and animals living in the aquatic and wetland environment.

Water

The discharge of dredged or fill material can change the water chemistry and the physical characteristics of the water body at the disposal site through the introduction of chemical constituents in suspended or dissolved form which do not occur there naturally. Changes in clarity, color, odor, and taste of water or the presence of toxic or hazardous pollutants can reduce or eliminate the suitability of water for use by aquatic communities, as well as for human consumption, recreation, aesthetics and amenities. The following are guidelines to minimize impacts to water.

1. Using upland disposal sites for

retention or treatment of runoff from the discharged material to remove dissolved pollutants before they reach the aquatic and wetland environment.

2. Using lined or impervious containment areas in waters of the U.S. to prevent exposure of the discharged material to the receiving water column.

3. Adding treatment substances to the discharged material. For instance, oxygen loss from the water column associated with biological and chemical oxygen demand can be reduced by the addition of oxygen to the discharged material flow.

Current Patterns and Water Circulation

The discharge of dredged or fill material can modify current patterns and water circulation by obstructing flow, increasing stratification, changing the circulation direction or velocity of the water flow, or otherwise reducing the reach of a water body. The following are guidelines to minimize impacts to current patterns and water circulation.

1. Distributing discharge material widely in a thin layer at the disposal site to maintain natural substrate contours and elevation.

2. Engineering the shape and orientation of a dredged material mound to minimize the barrier effect to the currents.

3. Ensuring water circulation by using properly designed culverts, pilings, bridge spans, etc., and using discontinuous mounds for open water discharge.

4. Selecting dam impoundment sites to minimize distortion of unique riverine ecosystems.

Normal Water Fluctuations

The discharge of dredged material can alter the normal water-level fluctuation pattern of an area resulting in prolonged periods or exaggerated extremes of high or low water, or a static nonfluctuating water level. Such water level modifications can increase erosion or sedimentation, aggravate water temperature extremes, upset the nutrient/dissolved oxygen balance, destroy populations of aquatic or wetland animals and plants, induce nuisance vegetation growth, restrict movement of aquatic or wetland fauna, and destroy spawning areas. The following are guidelines to minimize impacts to normal water fluctuations.

1. Designing access roads and channel-spanning structures using culverts, open channels, and flow diversions which allow both high and low stages of fluctuating water flows, and which maintain circulation.

2. Designing the discharge of dredged or fill material to minimize or prevent the creation of standing water bodies in areas of fluctuating water levels, or the drainage of areas previously subject to such fluctuatio

Special Aquatic Sites

In addition to guidelines to minimize impacts to physical, chemical and biological components of the aquatic and wetland environment the following Special Aquatic Sites are addressed in the S404(b)(1) Guidelines:

1. Sanctuaries and refuges
2. Parks, historic monuments, National seashores, wilderness areas, and research sites
3. Wetlands
4. Mud flats
5. Vegetated and unvegetated shallows
6. Coral reefs
7. Riffles and pools

The discharge of dredged or fill material into these areas can reduce aquatic and wetland habitats, interfere with spawning, migratory or other life-stage activities, and reduce the availability of food for fish and wildlife. Discharges of dredged or fill material may increase undesirable human presence by providing persons ready access to remote areas or requiring frequent maintenance activity. Some of the more significant guidelines to minimize impacts in the ahove areas are the following.

1. Discharging at times other than breeding, migrating or other critical life-stages of fish, wildlife and other aquatic or wetland organisms.

2. Restoring the elevation, substrate type, and drainage characteristics immediately following the completion of any construction or other discharge activity in a wetland to provide conditions for natural restoration of vegetation in disturbed areas.

3. Establishing new wetlands with disposal material where suitable sites and conditions exist and other components of the ecosystem, such as vegetated shallow water areas, will not be disrupted.

4. Selecting sites or managing discharges to confine and minimize the release of suspended particulates, which would result in reductions in light penetration or increase

in turbidity levels in the proximity of a coral reef.

5. Locating and containing the discharge of dredged or fill material away from riffle and pool areas to minimize or prevent changes in stream hydrology which would cause significant increases in scouring or sedimentation of riffles and pools.

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Benefit/Cost Analysis as a Basis for Compensation and Mitigation Decisions for Hydroelectric Projects[1]

Ken G. Peterson[2]

Evaluation techniques applied to non-marketed environmental resources can be utilized in both benefit/cost analyses of hydroelectric projects and in mitigation and compensation decisions. Acceptance of a common analytical framework greatly facilitates negotiations between developers and resource agencies. Principles are illustrated in this paper by an analysis of a current hydroelectric proposal for the Peace River in northeastern British Columbia.

INTRODUCTION

Land and water use decisions in British Columbia are becoming increasingly complex. Alternative uses of resources are both more numerous and better represented amongst government agencies and public interest groups than ever in the past. As a consequence, the information that must be generated and the negotiations that must be carried through have changed dramatically even though statutory requirements under the Water Act and other legislation have not.

In the last 3 years both the Canadian and British Columbia governments have developed guidelines for evaluating public investment projects based on benefit/cost analysis. This framework provides a consistent basis for comparing alternative uses of resources, namely their contribution to provincial or national income in one use compared to another. The information generated forms a basis for public decision-making on both the economic feasibility of a project, and the values lost (opportunity cost) of environmental resources committed to development.

Detailed environmental resource studies have recently been completed for the proposed Peace River Site C dam in northeastern British Columbia. Forestry, agriculture, river-orient recreation, and fish and wildlife are among the many alternative uses of the land and water resources of the proposed reservoir. Part of the public decision making process for this proposed development includes negotiation with government agencies, communities and others over proposals for mitigating impacts or, where mitigation cannot be achieved, compensating for them. The evaluation of the resources involved using benefit/cost techniqu forms the basis for the negotiations and establishes a guide to the magnitude of compensation and mitigation expenditures. Policies for dealing with these issues are now beginnin to be established in British Columbia. This paper illustrates B.C. Hydro's approach with the Peace River Site C project as a case study.

ANALYTICAL FRAMEWORK

Social benefit/cost analysis, as a decision-making tool, is designed to test whether the value of the yield of a course of action (benefit) exceeds the value of what the best alternative course of action would yield (opportunity cost). When applied to a public project the benefit is the value to society of the output of the project and the opportunity cost is the value to society of the activity displaced by the public project.

Social benefit/cost analysis differs from corporate financial analysis in both the range of costs and benefits included in the analysis and in the values attached to those costs and benefits where market prices do not fully reflect value. The analysis is based on the competitive model of economic theory in which all scarce resources are privately held by numerous owners with none having preponderant market power, all resources are readily divided among the owners, and no external or "third party" effects occur with any resource use. If these stringent conditions held in the economy then there would be no difference between the aggregate of individual private decisions and the results of a social benefit/cost analysis.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

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The competitive model establishes a reference point for evaluating allocative results in the real world, pointing out where markets fail and the direction and magnitude of adjustments to be made to observed prices. Resources in B.C. are generally not held in private hands. With the exception of farm and residential lands, resource ownership is primarily retained by the Crown. Natural attributes such as wildlife, public lands, water, or forests are common property resources (owned by all), with utilization managed mainly by provincial government agencies. The common property status of many of British Columbia's natural resources means that there are no private owners of, for example, wildlife resources, to press forward with demand for payments, if wildlife is damaged by a development. The relevant public agencies have the responsibility for managing and protecting resources, but since the agencies cannot operate as owners within the market system, their positions are necessarily weakened. Also, the lack of competitive numbers of buyers and sellers within natural resource markets means that prices are either nonexistent, or do not necessarily reflect the true social value of the resource in question.

Public ownership has to date meant that public resource losses associated with developments are often not compensated and since the resource opportunity costs of projects are not consistently imposed on developers, the price of final outputs does not reflect the value of opportunities foregone. Thus, the consumers of the final product receive an implicit subsidy at the expense of the general public, in that the public bears costs which remain uncompensated. On the other hand, if government agencies press for compensation payments which exceed the value of resources lost, then the users of those resources also receive a transfer or subsidy.

The distribution of costs and benefits of a project, i.e. who gains and who loses, and the equity of such distributional effects are also important. Inferences drawn from the competitive model are limited to the determination of efficiency in resource allocation. Analysts can point out the distributional consequences of a resource development, in terms of effects which fall more heavily upon some groups than others, but the test of the desirability of these effects must be made at the political level.

It is important, however, to identify who the losers are and how severely they are affected to provide the essential information for compensation and mitigation decisions.

COMPENSATION AND MITIGATION

With the appeal of B.C. Hydro's Sevel Mile project water licence in 1975 a formal debate began in British Columbia over the extent to which environmental impacts should be mitigated or, if unmitigable, the amount of compensation for damage that should be paid and to whom the payments should be made. The issues were not new in that major developers, including B.C. Hydro, had previously made design changes to avoid impacts, and some compensation payments had been made. As a result, B.C. Hydro is currently in the process of adopting a formal policy which is being applied to the Peace River Site C project.

Definitions

Mitigation measures are ones which may be taken in the planning, design, or operation of a project to lessen adverse impacts on resources affected by the project. The cost of these measures becomes part of direct project costs. In principle, mitigation measures should bring about at least as valuable a reduction in resource losses as the cost of the measures themselves. If good information is available on the value of impact reduction then mitigation measures become a part of project optimization analysis. Compensation payments, on the other hand, are made either in cash or in kind, for resource costs which are not eliminated by mitigation measures. For example, maintaining stream flows to protect sport fish would be a mitigation expenditure, and money spent on fisheries management or enhancement would be compensation. A case for compensation and mitigation expenditures can be made on either economic efficiency or on equity grounds. There are also different implications for how the expenditures should be made once the amounts have been estimated and these are reviewed in each case.

Efficiency Considerations

Compensation payments made for economic efficiency reasons would go to the Crown to cover the cost of resources used or damaged by a development. The payment structure would ensure that benefits from a project would cover all the costs. An incentive would be provided for both the developer and agencies with a management responsibility for resources to calculate carefully the value of the impacts. A second efficiency consideration aided by actual payment is the incentive provided to examine design alternatives to reduce or eliminate the effects at a lower cost than full compensation. Thus both mitigation and compensation expenditures would be better rationalized with a system which requires actual payment. A third consideration on efficiency grounds is that actual payments would be reflected in the price of the product, and thus the price would include full social costs.

Efficiency payments for the use of Crown resources would be made to the Crown, i.e. general revenue. They would not be tied, in principle, to any subsequent program. Payments for forest losses, for example, would not go to the Forest Service for further forestry expenditure. Nor would efficiency payments necessarily be applied in the region affected. They would be a source of revenue, like any other, to be allocated by the political process to whatever ends are deemed most desirable.

Equity Considerations

The effects of development projects vary significantly by region and by sub-groups within the population. Expenditures for equity purposes would return some of the economic benefits generated by a project to the regions and groups that lose the most as a result. Equity payments would have two characteristics. They would be made when a community or region suffers relative to the province as a whole, and they would be paid to agencies for the purpose of making compensating investments in the region. Where resources can be evaluated, payments on equity grounds would be guided by the value of the resource affected. Where intangible resources are at issue, acceptable payments would have to be negotiated and sanctioned by appropriate political or judicial processes.

Physical Replacement

A common argument for compensation expenditures is that they should be made in order to replace where possible the physical assets impaired by development. This argument abstracts from use, and therefore value in the economic sense, of the resource and cannot be supported on either economic efficiency or equity considerations. Within the value framework of benefit/ cost analysis the only supportable position on compensation and mitigation is the one guided by the value of the resource affected. Resources which are physically equivalent but support different levels of use would thus be treated differently Of course, this is not the only value framework and it is not universally applicable, but it has been a highly useful approach in British Columbia to resolving resource use conflicts.

B.C. HYDRO'S APPROACH TO COMPENSATION AND MITIGATION

a) Mitigation and compensation payments will be guided by the value of the resources affected. Physical replacement through enhancement will not be an objective unless it can be justified on the basis of present and future use.

b) Mitigation expenditures would be made for either economic efficiency or equity reasons. The goal would be to make those expenditures which increase the net social benefits of a project.

c) Compensation payments would be made for equity reasons to maintain social and environmental well-being in the regions affected by development.

d) Compensation payments would generally be made to the agencies directly responsible for the resources affected and would be used to benefit the region affected.

THE EVALUATION OF RESOURCES IN THE PROPOSED PEACE RIVER SITE C IMPOUNDMENT AREA

Environmental resources which would be affected by the proposed Site C dam can be divided into several categories: market versus non-market, private versus Crown ownership. These categories are not mutually exclusive which suggests some of the ambiguity involved in environmental resource evaluation. Table 1 shows an evaluation of the resource impacts of the proposed Peace Site C dam. The numbers are based on studies done by consultant for B.C. Hydro and represent the middle value of the range of the estimates provided.

In the case of agricultural land held in private hands, for which markets exist both for the output and for the land itself, there is in British Columbia a presumption, supported by legislation, that social value exceeds market value. The reference is to the B.C. Land Commission Act and the Agricultural Land Reserves established under it. In the eyes of the Land Commission the purchase price paid to the private land owner does not reflect its full future value given shortage of agricultural land in B.C. Therefore it is necessary to evaluate this resource on an "as if" basis showing the value of the land under alternative assumptions about the future supply of and demand for agricultural production. This exercise is designed to correct for the perceived shortsightedness of present markets and it assigns a higher social opportunity cost to the land than the amount actually required to turn it from one use to another.

TABLE 1

THE SOCIAL COST OF RESOURCE IMPACTS
OF THE PROPOSED PEACE SITE C
HYDROELECTRIC PROJECT
($ Thousands 1979)

Resource	Value in Present Use	Nature of Impact	Value With Peace Site C	Net Social Cost[1]
Fishing	8,323	loss of angler days	1,800	6,523
Hunting	2,226	loss of hunter days	1,678	548
Recreation	41,661	loss of river based recreation	3,905	37,756
Guiding	125	loss of guiding income	123	2
Trapping	696	loss of pelt production	686	10
Agriculture	9,047	loss of vegetable production capability	1,774	7,273
Forestry	356	lower annual allowable cut	-	356
	62,434		9,966	52,468

[1] Present discounted value at 6 percent over 70 years.

Forest resources and wildlife-based guiding and trapping activities can be evaluated through market prices and cost and return data. In the proposed Peace River Site C dam area, rights to some of these resources are held in private hands, and some in Crown ownership. The social opportunity cost is the same, regardless of ownership, but the rules for compensation differ. With private ownership or private holdings of rights to Crown resources, compensation is the same as for private property. Rules for compensation for resources held by the Crown are still evolving.

Commercial uses of fish and game through guiding and trapping are only a small part of the value of these resources. Fishing and hunting are much more valuable activities but, because of a tradition of free access to the public domain in B.C., no charges are levied, apart from annual licence fees which are not charges for the activities per se, and thus there are no market reference points for determining the value of the land supporting fishing and hunting. It is necessary to utilize techniques which have come into common use over the past 10 to 15 years and which now have fairly broad acceptance for establishing the value of these resources. Surveys of fishermen and hunters are done to estimate both the amount of activity and the value of it to the participants. Techniques for estimating the willingness of fishermen and hunters to pay for their activity, if they had to, are not without controversy, but sufficient experience has been built up to have confidence in the results for use in the benefit/cost decision framework.

Access to recreation other than fishing and hunting is also free on public lands and waterways. In the case of the proposed Peace Site C dam area, general recreation activities such as boating, hiking and picnicking outweigh fishing and hunting in importance. Estimating the amount of such activity and evaluating it is more difficult, however, because no licences are required. Therefore, surveys had to be made of the whole population in the area and then values in terms of dollars per recreation day attached to the calculated number of days of recreation.

The evaluation of resources over time includes assumptions about the value of those resources in the future compared to other commodities. The literature on environmental resource evaluation argues that because irreplaceable resources such as free flowing streams are fixed in quantity, their value will rise over time relative to other goods and services at about the rate at which the production of other goods and services becomes more efficient, that is, at the rate of change in technical progress. Thus the middle of the range of value for general recreation shown in Table 1 is based on a 3 percent per annum increase in relative value while the upper end reflects a 6 percent increase per annum in relative value. Comparable assumptions were used in the evaluation of the other resources in Table 1.

The Lower Peace Valley is scenically highly aesthetic and while the reservoir would not alter the contours of the river significantly, much of the interest and variety would be lost due to the flooding of the islands in the river. The value of the difference in visual quality may or may not be significant; there is no satisfactory method of evaluating scenic resources. Similarly with heritage resources that would be lost. The Peace River was a conduit for the early European penetration of the area as well as a focus for native settlement. There are obvious cultural and historical values at stake but what importance should be attached to them? Again we have no satisfactory method for suggesting even an approximation of value. Neither of these items is included in Table 1 or in compensation and mitigation proposals.

The resource costs shown in Table 1 have equity implications in that the major impact of the losses would be felt by residents in the Peace region. Thus a case can be made for making mitigation and compensation expenditures on the basis of reducing the social costs of the project incurred in the local area. Table 2 and 3 illustrate the type of mitigation and compensation measures which might be taken. These are illustrative because they have not been approved by B.C. Hydro nor have they been negotiated with the appropriate government agencies. Nevertheless, the tables do show the order of decision-making on mitigation and compensation. The major design or construction changes that have been proposed to mitigate impacts are: 1. to clear the reservoir, which is B.C. Hydro's policy, and 2. to provide access, perhaps across the dam, to the undeveloped land on the south bank of the river.

Clearing the impoundment area would substantially reduce the impact on recreation because it would make the reservoir available for recreational activity. However, the final column of Table 2 indicates a significant residual impact on the region which suggests scope for compensation. Furthermore, some impacts are not reduced by mitigation expenditures. Table 3 shows the type of compensation measures which might be taken to alleviate further the impact on the region. These include the provision of facilities on the reservoir for camping, boat launching and picnicking to make it more accessible. Also, fisheries enhancement and wildlife management programs could be funded to leave the region essentially as well off as before in terms of fishing and hunting opportunities.

Two other types of compensation are illustrated in Table 3. The impact on wildlife based guiding and trapping activities could be compensated by direct payment to those affected. An alternative to providing access to undeveloped agricultural land on the south bank would be to recommend the removal of the existing flood reserve on land downstream on Site C. It is felt that this reserve has inhibited the normal development of the more highly valued crops such as vegetables because of the deterrent to investment in grading and processing facilities. Removal of the flood reserve would allow the industry to develop and may serve to protect the future of agricultural capability in the region. This may also serve to alleviate some of the concerns over the long term erosion of agricultural production in the province as a whole.

TABLE 2

MITIGATION MEASURES FOR RESOURCE IMPACTS OF THE PROPOSED PEACE RIVER SITE C HYDROELECTRIC PROJECT

($ Thousands 1979)

Resource	Mitigation Measure	Cost of Mitigation	Remaining Resource Impact[1]
Fishing	Reservoir Clearing	7,000	2,017
Hunting	-		548
Recreation	Reservoir Clearing		19,399
Guiding	-		2
Trapping	-		10
Agriculture	-		?
Forestry	-		356
		7,000	22,332

[1] Present discounted value at 6 percent over 70 years.

TABLE 3

COMPENSATION MEASURES FOR RESOURCE IMPACTS OF THE PROPOSED PEACE SITE C HYDROELECTRIC PROJECT

($ Thousands 1979)

Resource	Compensation Measure	Cost of Compensation	Remaining Net Social Cost[1]
Fishing	Incubation boxes	400	-
Hunting	Wildlife Management	500	-
Recreation	Camping, boat launching, picnic facilities	1000	5916
Guiding	Payment to guides	2	-
Trapping	Payment to trappers	10	-
Agriculture	Remove downstream flood reserve	-	-
Forestry	-		356
		1912	6272

[1] Present discounted value at 6 percent over 70 years.

Finally, the point made in Tables 2 and 3 is that relatively modest sums spent on compensation and mitigation measures, if intelligently planned and executed, can go a long way towards maintaining the well-being of the affected region. Whether this will be sufficient in terms of the expectations of government agencies and the people in the area will only be determined when B.C. Hydro actually applies for a water licence and begins negotiations on compensation and mitigation.

CONCLUDING REMARKS

Environmental resource impacts have become highly prominent and contentious issues in hydroelectric planning in British Columbia in recent years. To respond to these issues both B.C. Hydro and the resource agencies of the provincial government have had to adopt new approaches both towards generating information on impacts and integrating this information into the decision-making framework for project licensing.

Social benefit/cost analysis is far from a new technique but its imaginative application to these problems can be a valuable aid both in making a public decision on a project and in guiding appropriate mitigation and compensation strategies. Opponents of hydroelectric projects are unlikely to be won over by benefit/cost analysis or by sophisticated evaluation techniques, but there has been a palpable shift in support recently from outright opposition and confrontation to a more rational assessment of alternatives. This is particularly noticeable in British Columbia among the government agencies and it is a trend which should be reinforced by a willingness on the part of utilities to present comprehensive evaluations of the impacts of hydroelectric projects.

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Dust Abatement Project with Wildlife Enhancement on Canyon Ferry Reservoir, Montana[1]

Don A. Childress[2] and Robert L. Eng[3]

Abstract.--Artificial marshes are being created in subimpoundments constructed at the U.S. Bur. of Rec. Canyon Ferry Res., MT for dust abatement. The construction of 11 mi of dike to enclose four ponds for a total of 1,900 acres was begun in 1973 and completed in 1978. Input from biologists during the initial design and construction stages has contributed to increased wildlife benefits. Wildlife response and vegetation development to date are discussed.

The Conservation and Wildlife Enhancement Program is a Bureau of Reclamation project that was completed in 1978 at Canyon Ferry Reservoir on the Missouri River near Helena, Montana (fig. 1). The project is primarily intended to mitigate several dust problems originating from exposed beaches when the reservoir is drawn down over winter for power generation and flood control. With input from wildlife biologists during the design and construction stages, the area is being developed toward productive waterfowl habitat.

Canyon Ferry was constructed by the Bureau of Reclamation in 1954 as a multipurpose power, flood control, irrigation and recreation project. During the first twelve years of operation water levels were kept high to maximize hydroelectric power generation. Drawdowns which occurred were generally of short duration.

In 1966, in order to meet flood control needs, water level management changed on the reservoir. Complaints of duststorms originating from the upper end of Canyon Ferry began. Under the new management plan, an estimated 4,600 acres at the upper end of the reservoir would be exposed during late winter and spring in three out of 10 years. As much as 9,100 acres could be exposed during years of low runoff(Denson et al. 1978).

The soils of the exposed lakebed are reworked material of volcanic origin and a high percentage of the material is fine-grained volcanic glass and ash. After several years of intermittent inundation, all vegetation covering was lost and the soil mantle broke down into a material highly susceptible to wind erosion.

Townsend (population 1,380) is located within two miles of the upper end of the lake. In 1966 residents began complaining of dust getting into their homes. Nearby ranchers complained of irritation to livestock and contamination of forage and hay crops. Motorists on U. S. Highway 287 were often required to use their headlights during daylight hours because of poor visibility. The Montana Department of Health reported the average deposition of dust in the Townsend area was in excess of 300 tons per square mile per month, which far exceeded the 15 to 20 tons considered acceptable.

In response to the numerous complaints, several dust suppression measures were undertaken. Attempts at drift fencing and corrugating of the beaches proved unsuccessful. Vegetation plantings were attempted but none could survive the combination of inundation during the growing season and the frost heaving in the root zone during winter.

By 1968, complaints intensified and groups such as the Broadwater Jaycees, Broadwater County Commissioners, and many individual residents urged that a permanent solution to the problem be investigated. As a result, the Bureau began a special two-year study to determine the best solution to the dust problem. The search was given further impetus when the Bureau was cited by the State Department of Health in April, 1971 for exceeding State air pollution standards.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, Colorado, 80523, on July 16-20, 1979. Published as Journal Series No. 965, Montana Agricultural Experiment Station, Bozeman, MT.

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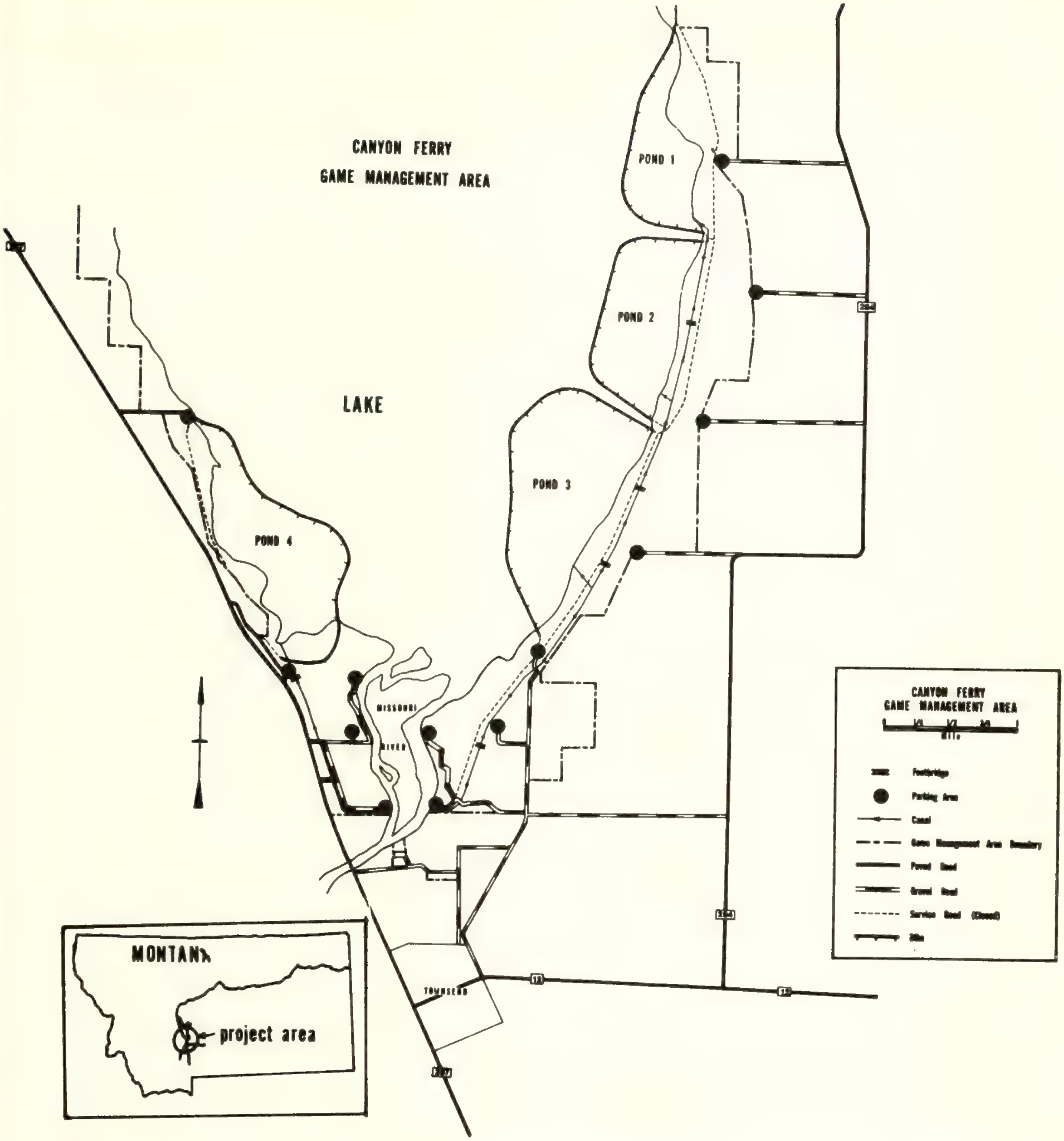

Figure 1.--Location of Canyon Ferry Project and distribution of wildlife enhancement ponds.

Later that year, Congress authorized the Bureau to start the Canyon Ferry Conservation and Wildlife Enhancement Project, a long term program which involved the construction of dikes to enclose nearly 1,900 acres of the exposed area and the excavating of an additional 2,700 acres. The material excavated from the reservoir side of the dikes would be deposited in the four subimpoundments.

Construction of the first four dikes began in 1973. Completion of the last dike was during the fall of 1977. Each of the four impoundments is provided with a water supply via canals from the Missouri River. Gated outlet structures on each dike permit the manipulation of water depths within the ponds for management purposes.

The dredging of the approximately 7.2 million cubic yards of silty material from the remaining 2,700 acres was done by the Western Pacific Dredging Corporation. The dredge sent a mixture of water, silt and rocks through a pipe to the point of discharge in the ponds.

The material was placed against the dikes and over gravel seams to act as a sealant. The remaining material was placed in the ponds at varying depths. It was anticipated that the varied water depths would create diversified zones of emergent and submergent vegetation beneficial to a variety of wildlife species.

The Montana Fish and Game Department was involved with the project as administrators of Bureau of Reclamation lands around the reservoir. Approximately 5,000 acres at the upper end of the reservoir as well as the ponds are managed as a wildlife area under an agreement with the Bureau.

In 1973 a cooperative study was initiated involving the Bureau of Reclamation, the Montana Fish and Game Department, and Montana State University. The construction schedule of the four ponds permitted an opportunity to record the sequence of ecological events and perhaps initiate measures during construction which would enhance the value of the area for wildlife.

Wildlife enhancement efforts involved the construction of islands within the ponds as nesting sites for Canada geese. Thirty islands were constructed utilizing the existing gravel and silt material on the floor of the pond. By the end of the first year, erosion by wave action had destroyed approximately 50 percent of each island. By the second year, nearly all silt type islands were gone. It was obvious at this point that islands would have to be constructed of rock or gravel material.

Gravel material of sufficient size to withstand erosion was lacking in the ponds. Heavy gravel material was hauled by truck during the winter and each island constructed with a beach on the side of the prevailing wind. Individual islands consisted of 350-400 cubic yards of material and were confined to water depths of one to four feet. Costs of construction varied between $600 and $1500 per island depending upon the length of the haul and year of construction.

In 1976 it became apparent that the amount of dredgable material had been underestimated by several 100,000 cubic yards. Initial plans for the placement of this additional material were to create a large reef area in Pond 3 with water depths of one to four feet. It was hoped that additional islands could then be hauled into this area.

A considerable amount of the material being pumped into this pond was coarse gravel. It was soon evident that islands could be built of this material to a height three to four feet above the water surface. The size and number of islands that could be built by dredging was limited only by the amount of gravel material available. Over 350 islands were built by the dredge. Since the material being pumped was part of the construction contract, there was no additional cost for the building of islands.

The establishment of aquatic vegetation within the impoundments has been slow. Unpredictable changes in construction schedules and high turbidity as a result of dredging activitie have been major deterrents in the establishment of aquatics.

Attempts have been made to accelerate the establishment of desirable aquatic species by seeding and transplants. Sago pondweed (*Potomageton pectinatus*) vegetative parts and seeds were distributed in the first constructed pond (Pond 4) in the fall of 1976. The followin spring individual plants were transplanted into selected areas. By 1978, although not widely distributed, the transplanted clumps had increased in size and seed production was evident.

Transplants of bulrush (*Scirpus sp.*) were made from local sources. These small scale plantings were heavily grazed by geese. Several thousand individual roots were obtained from a commercial source and were fenced at planting to protect them from grazing geese. Excellent growth and expansion of the plants was noticed the first year.

Photo plots and sampling transects have been established to monitor vegetational changes as they occur. Color infrared aerial photography is being employed to monitor the gross vegetational changes from year to year. These aerial photos will also be used to compare relative degrees of turbidity in the ponds.

The most dramatic response to the project by wildlife has been by Canade geese (*Branta canadensis*). Prior to the project's beginning, a small population of Canada geese were nesting in association with the river as it enters the upper end of the reservoir. Annual production from this flock fluctuated greatly since nests were often destroyed by flooding from rising water levels in the reservoir. Breeding pair counts and nest site distribution of this segment suggested a saturated habitat with secure nest sites being the limiting factor. From 1974 to 1979, nest searches on the river revealed a high of 50 goose nests and a low of 30, in 1978 and 1979 respectively.

Nesting islands were first available in Pond 4 in 1974 when six goose nests were located. As shown in figure 2, use of the islands by Canada geese has steadily increased. The number of nesting geese has nearly doubled since the project began, primarily through the

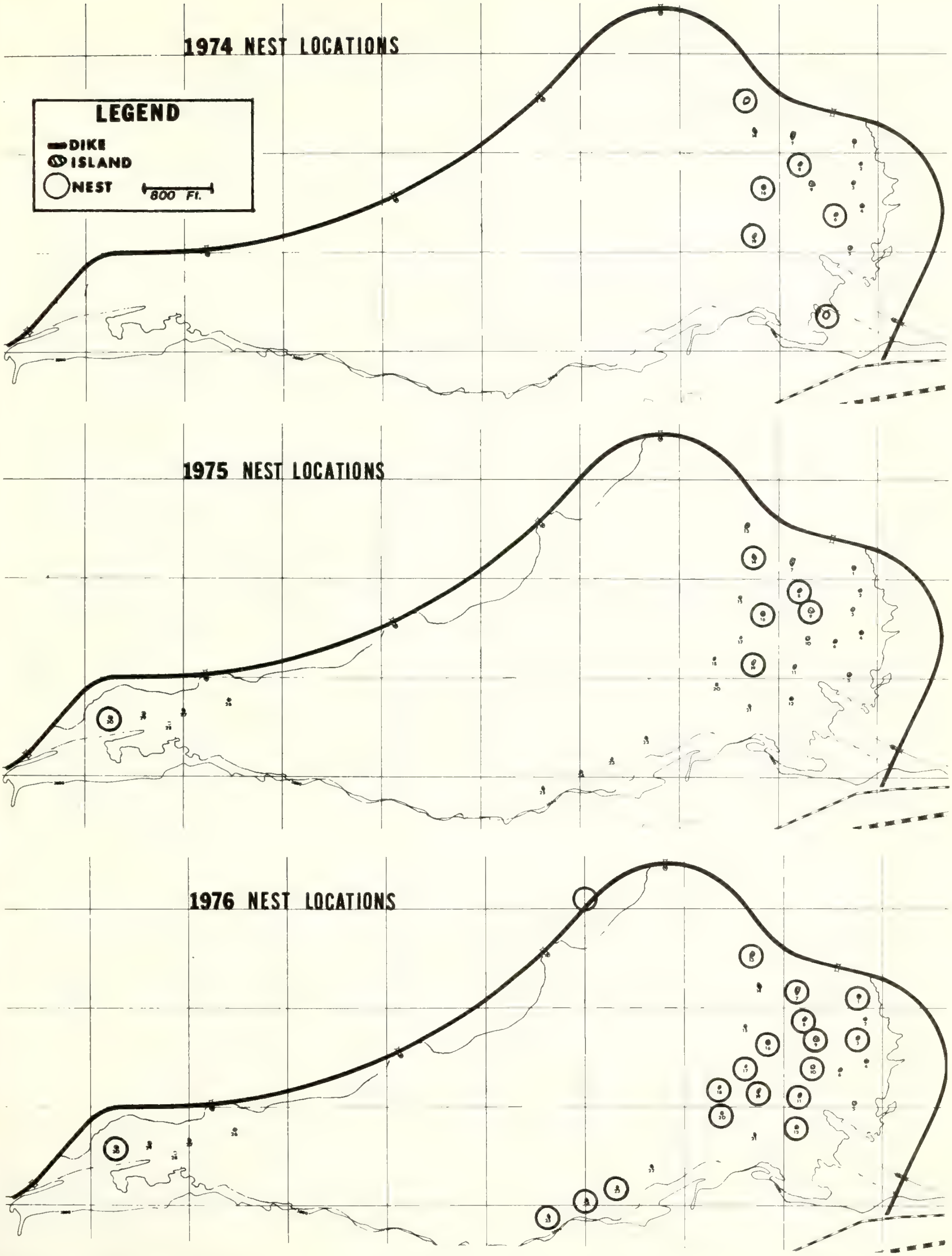

Figure 2.--Numbers and locations of nesting geese in Pond 4, 1974-79.

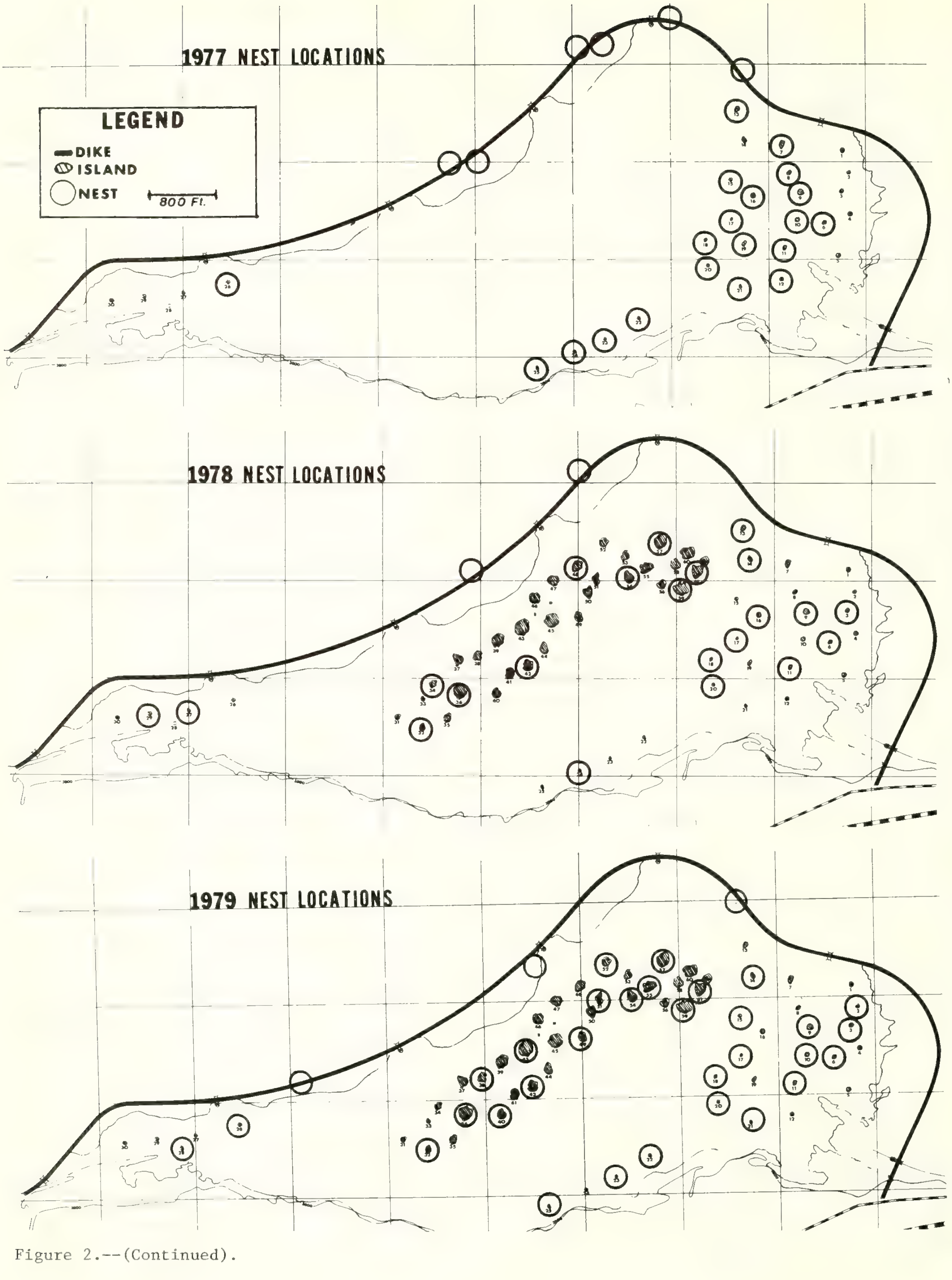

Figure 2.--(Continued).

use of islands constructed in the ponds (Table 1).

Table 1.--Distribution of goose nests on Missouri River and Ponds, 1974-1979.

Year	Ponds	River
1974	6	47
1975	6	45[1]
1976	18	42
1977	39[2]	43
1978	42[2]	50
1979	51[2]	30

[1] Based upon aerial survey.
[2] Includes six nests on dikes in 1977, three in 1978 and five in 1979.

The islands constructed in the impoundments have provided more secure nest sites when compared to the river islands. In 1978 nest success in ponds was 80% compared to 50% in the river. This high success rate of impoundment nesting geese has resulted in a greater than threefold increase in gosling production (Table 2).

Table 2.--Gosling production on Canyon Ferry Project, 1973-1979.

Year	Maximum Count	% Increase
1973	109	
1974	163	49
1975	202	23
1976	147 (250)[1]	23
1977	302	20
1978	237 (325)[2]	8
1979	453	39

[1] High water and excessive cover. Supplemental counts indicating 250.
[2] 325 based on ratio of marked (199) to unmarked birds.

By 1976 most newly constructed islands were still devoid of vegetation which could be used as nesting cover. In an attempt to attract geese to the islands, nesting structures comprised of two driftwood logs placed in a V-shape and a small amount of straw were placed on most islands (fig. 3). Of the 136 nests located on islands in the ponds from 1976 to 1979, 93 percent were located in the structures.

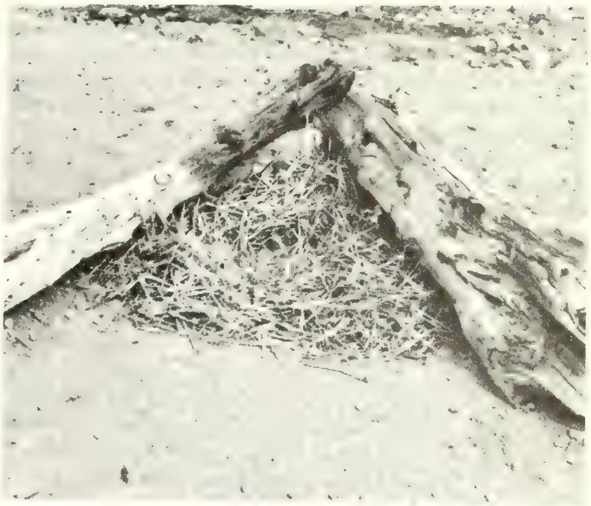

Figure 3.--Driftwood nest structure on newly constructed island.

Use of the area by other waterfowl has been more difficult to quantify. Duck broods were absent on the area in 1973. By 1978 an estimated 40 to 50 broods were produced on the project. With the absence of significant aquatic vegetation in the ponds, most duck broods have been associated with the water supply ditches. Future use by breeding ducks is expected to increase significantly with the establishment of both submergent and emergent vegetation in the ponds.

Spring and fall use by migrating waterfowl has steadily increased over the six-year period. In 1979, 250,000 ducks, 7,000 snow geese (*Chen hyperborea*) and 3,000 swans (*Olor columbianus*) were observed on the area during spring migration.

A breeding colony of California gulls (*Larus californicus*) and ring-billed gulls (*Larus delawarensis*) was established in Pond 3 in 1977. Nesting efforts of this colony were largely unsuccessful during 1977 and 1978 due to conflicts with construction activities.

Nesting pairs of osprey (*Pandion haliaetus*) have increased in the immediate vicinity of the ponds from one pair in 1974 to five pairs in 1977. This increase is probably a response to the additional shallow feeding areas provided by the ponds which Swenson (in press) alluded to as a preferred feeding habitat for this bird. A powerline was established on Dikes 2 and 3 to provide power for the dredging operation. Nest structures were placed by the dredge company on four power poles which were left standing in widely distributed sites. Black-necked stilts (*Himantopus mexicanus*), Bonapartes gulls (*Larus philadelphia*), black-bellied plovers (*Squatarola squatarola*) and snowy plovers (*Charadrius alexandrinus*) have been recently observed on the project for the first time.

The ecological changes occurring as a result of this project are continuing, resulting in an increase in wildlife numbers and species. Critical to this increase is the diversity in habitat conditions present on the project. Such conditions would not have been achieved had not the expertise of engineering, construction and biological personnel been incorporated during both the design and construction phases of the project. Although this project was precipitated by a single problem, that of dust abatement, the input from several disciplines from the very start of the project resulted in far broader benefits.

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Strategies for Mid-Columbia Fish Production[1]

By V.W. Kaczynski[2] and D.W. Moos[3]

I. INTRODUCTION

This paper discusses the concept and advantages of area-wide fisheries mitigation management of water bodies as it applies to the Mid-Columbia River.

Three Mid-Columbia River Public Utility Districts have invested considerable funds (over $10 millon pre-1970 dollars) in salmonid propagation facilities to mitigate spawning habitats inundated by five hydroelectric projects. Very large operation and maintenance budgets are also involved. Washington State Departments of Fisheries and Game operate these propagation facilities.

Individual fisheries mitigation agreements have evolved for each project somewhat independently. The present total mitigation goals to replace the production of inundated spawning habitats comprise about 65,000 pounds (150,000 fish) of rainbow trout; 78,000 pounds (520,000 fish) of steelhead trout; and 116,000 pounds (4,640,000 fish) of chinook salmon. Each PUD is responsible for its portion of the mitigation and each operates individual facilities to accomplish this. The PUDs and the state agencies are however moving toward combined waterway mitigation management, which appears to be beneficial to the fisheries, more productive, and much more cost-effective.

II. FACILITIES INVOLVED

Washburn Island: Most northern facility, near Brewster on the north (west) side of the Columbia River; a 120-acre diked oxbow channel with potential for up to 50 cfs inflow of ambient river water; juvenile collection facilities in downstream dike; internal circulation poor; serious temperature, disease, predator, and fish handling problems; abandoned since 1972.

Wells Facility: Complex facility near Azwell; adult trapping and holding facilities; spawning channel for 6,000 adult summer chinooks (over 1 mile long with 142 cfs maximum flow of ambient river water); two 1.5-and 6-acre rearing ponds; tray-type incubation facility for 15,000,000 eggs; inside fry starter trays (800,000 fry); six conventional outside raceways (each 9x4x90 feet); maximum of 18 cfs excellent quality ground water; seasonal suboptimal temperatures and seasonal disease problems (with ambient river water).

Chelan Falls Hatchery: Traditional trout hatchery near Chelan Falls; indoor incubation-fry starter trays and concrete raceways; concrete outdoor raceways; capacity for 90,000 rainbow trout and 195,000 steelhead smolts reusing 4 cfs ground water (60 percent reuse, aerated); facility designed for 16 cfs ground water but ground water flow cannot be maintained; chronic disease threat because of reuse.

Rocky Reach Annex: Immediately below Rocky Reach Dam; five vinyl-lined framed raceways (8x4x87); incubator racks within raceways; up to 12 cfs of good quality toe-drain water (naturally filtered and temperature buffered Columbia River water); facility presently used for incubation and early fry rearing in conjunction with Turtle Rock.

Turtle Rock Island: Within east side of upper forebay of Rocky Reach Dam; intake pump house and aerator yielding up to 60 cfs ambient river water; adult trapping and holding facilities (inactive); four spawning channel sections (900 linear feet); a 2-acre rearing pond (inactive); seasonal suboptimal temperatures and seasonal disease problems; spawning gravels now removed and channel sections used as flow-through nursery raceways; facility now being replumbed and channel sections will be independent nursery raceway sections.

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Priest Rapids Facility: Most southern facility, immediately below Priest Rapids Dam; adult trapping and holding facilities; 100 cfs maximum inflow of ambient river water; 6,050-foot spawning channel (capacity for 5,000 fall chinook adults); 23-acre rearing pond; tray-type indoor egg incubation station (10,000,000 capacity); 6 cfs high quality well water verified, 20 cfs probable, 50 cfs possible.

III. PRESENT PRODUCTION

Individual PUD commitments presently take place at individual PUD facilities. Production, water quality and disease records were reviewed and summarized at all facilities to determine physical and biological constraints of each facility.

Turtle Rock and parts of the Wells and Priest Rapids facilities were originally designed using spawning channel technology as the primary method of meeting mitigation goals for chinook salmon. This has generally not been successful. Chinook production has been highly variable year to year in terms of number, size and health of smolts produced. It was agreed that raceway culture has much better potential. Estimates of numbers and poundage of smolts were subsequently made to convert spawning channel mitigation goals into corresponding raceway production goals. This yielded the 116,000-pound annual production goal estimate (4,640,000 smolts at 40/pound).

Current rainbow and steelhead production at Wells and at Chelan Falls is 65,000 pounds of rainbow and 78,000 pounds of steelhead. Conventional raceway and pond culture is used, and in general, these programs have been successful. With some overall operation changes, they could be even more successful.

IV. COMBINED PRODUCTION STRATEGIES

1. Steelhead Trout: The Wells production facilities are capable of producing healthy steelhead smolts. This is probably the best long term use of this facility. Production capacity (as modified herein) can meet present and anticipated mitigation requirements for all the Mid-Columbia PUDs. The largest obstacle limiting production is an inadequate supply of cool well water needed to bring first year fry through the late summer when river water temperatures are warmer than is desirable. Some 106,000 pounds (700,000 smolts at 6.6/pound) could be reared considering this ground water seasonal limitation. The present program calls for some 78,000 pounds production (514,000 smolts at 6.6/pound). The Chelan Falls Hatchery can be used successfully to supplement adult holding and egg taking. An additional 40,000 pounds (264,000 smolts at 6.6/pound) can be reared through an integrated plan involving Wells, Rocky Reach Annex, and Turtle Rock. This plan is discussed in more detail in the Rocky Reach/Turtle Rock section.

2. Rainbow Trout: Chelan Falls Hatchery will become primarily a trout hatchery. This hatchery, with its present 4 cfs water supply, could adequately handle the total rainbow requirements for the Douglas and Chelan County obligations (there are no present Grant County obligations).

3. Chinook Salmon: Two races are involved: summer and fall chinook. Except for the earlier upstream migration of summer chinook adults, their life cycles (and rearing requirements) are similar. The earlier upstream migration, and subsequent extended adult holding period of summer chinook, impose difficult logistical problems in maintaining the health of these fish under captivity.

3a. Summer Chinook: Conceptual facility provisions have been made for artificially rearing summer chinook at Wells and at Rocky Reach Annex/Turtle Rock. However, adult holding will remain a problem because of the extended time period before gonad maturation and because optimal holding water is not available at Wells. The probability of rearing a suitable quantity of summer chinook smolts is thus decreased (compared to fall chinook rearing) because of the adult holding difficulties.

The limited ground water supply at Wells has traditionally been used for holding adult steelhead and then for getting young steelhead fry through their first late summer. This limited supply continues to be needed to meet steelhead requirements. There presently is no verified ground water supply at Turtle Rock. Ground water records are presently being reviewed to determine whether a suitable quantity possibly exists. If more ground water is verified at Priest Rapids, provisions could be made for holding adult summer chinooks there. Thus, adult holding will presently have to continue at Wells in the lower spawning channel sections using ambient river water at full conduit flow (142 cfs). Artificial spawning will have to continue at Wells because of the adult holding limitation.

Eyed eggs can be successfully incubated at the Wells incubation station using river water. Fry can then be reared in modified channel sections at Wells (raceway nursery technology). The probability of meeting mitigation goals will be much higher than under present spawning channel technology. The report section on Wells facilities addresses this subject in more detail.

A higher probability of successful summer chinook fry production exists if eyed summer chinook eggs are transferred to the Rocky Reach Annex for incubation and subsequent early fry rearing. This would use the good quality toe drain water. Fry would then be transferred to Turtle Rock, where modified channel sections would be used to finish the fry to 40/pound using river water (raceway nursery technology). Refer to the Rocky Reach/Turtle Rock report section for more details on this alternative. Approximately 40,000 pounds (1,600,000 smolts at 40/pound) of high quality fry could be reared.

3b. Fall Chinook: Many good quality fall chinook smolts can be produced at modified Priest Rapids facilities. Adult holding is less critical (in large part because of shorter holding time), and optimum quality ground water can be used to meet much of the holding requirement. Modified facilities and production strategies should result in the capacity to produce 396,000 pounds of good quality fall chinook smolts at 40/pound (15,840,000 smolts). This compares to the present total mitigation goal of about 116,000 pounds of both summer and fall chinook smolts. The Priest Rapids facility section contains more details.

Chelan County PUD's mitigation agreement originally was for fall chinook smolt production (500,000 smolts at 40/pound). Although conceptual design in this report deals with summer chinooks, fall chinooks could be reared. Adult holding could take place at Priest Rapids, and eyed eggs would subsequently be delivered to the Rocky Reach Annex. The probability of success is greater with fall chinook than with summer chinook because of fewer problems in adult holding.

V. CONCEPTUAL FACILITY DESCRIPTIONS

Washburn Island: This facility will remain inactive for the foreseeable future.

Chelan Falls Hatchery: Under a combined mitigation program, the Washington State Game Department would use this facility primarily to rear rainbow trout. With no modifications, the total rainbow mitigation goal (65,000 pounds - 150,000 fish) could be adequately handled. The facility also could be used to hold some adult steelhead, for steelhead egg taking, and possibly for limited early fry rearing.

Wells Facility: Wells has the potential for rearing any salmonid. Location and logistics favor steelhead rearing. As long as the Washington State Department of Fisheries includes artificial propagation of summer chinook salmon in its management plan, the facility is also presently critical for this. Depending on verification of amounts of ground water at Turtle Rock and/or Priest Rapids, this criticalness for summer chinook could disappear.

The limitation for steelhead production at Wells is related to the limited ground water supply during the late summer (about 15 cfs). This supply is used to hold maturing adult steelhead and for oversummering steelhead fry. Because of this, adult summer chinooks must be held in river water. This is logistically difficult. Adult summer chinook holding difficulties create an uncertainty in the summer chinook program (potential disease outbreak).

If steelhead egg incubation can take place at the Rocky Reach Annex, only provisions for extra steelhead adult holding and spawning would have to be made at Wells (or Chelan Falls). Otherwise, additional provisions would possibly have to be made for initial fry rearing. We have not addressed these in our study.

Modifying several (4 for steelhead, 4 for chinook) of the spawning channel sections to make them independent raceway nursery vessels increases the capacity for chinook and steelhead fry rearing. These modified sections offer some logistical advantages over the existing ponds in terms of fish feeding, observing, sampling, and perhaps more important, cleaning, disease prevention, and disease treatment. Raceway modification specifications appear to be best if kept general and flexible. Early fry could be reared in alternate raceway sections and then half the fry could be transferred to the adjacent downstream raceways. Because of the options available to Washington State Game Department in rearing steelhead (6 conventional raceways, ponds, and modified channel raceway sections), the sharing of the facility with Washington Fisheries, and our limited study budget, we have not developed a detailed strategy plan for steelhead production at Wells. This needs to be done.

Summer chinook adults at Wells must be held in ambient river water. The best place to do this is the last several channel sections, with gravels removed, receiving full river conduit flow (142 cfs). The general fish-temperature-flow propagation rule, i.e., whenever temperatures are warmer than desirable, increase flow to compensate, is applied here. This operational mode for holding adults has been successfully used at Wells, although disease is still a constant danger.

Some 3,000 adult summer chinooks must be successfully held. Fifteen hundred (1,500) females should yield 7,158,000 viable eyed eggs. Of these eggs, 1,895,000 will be transferred to the Rocky Reach Annex. This leaves 5,263,000 eggs to be incubated in the Wells incubation station using ambient river water. Surplus incubation racks exist.

Initial fry would be transferred to two replumbed alternate channel sections (i.e., 1 and 3) as they swim up. These channels could be divided by temporary screens or perforated plates if additional size segregating is desired. Water velocities are mild; ambient river water would be used. Growth of these early fry should be slower than at Priest Rapids or Rocky Reach. At 250/pound, the fry would be manually crowded and 50 percent from each channel section would be siphoned into the adjacent downstream channel sections (i.e., from 1 to 2, and from 3 to 4).

Fry would complete their cultured growth here. Velocities and flow would increase about threefold during this period. Growth will probably reach 40/pound in June and the fry would be released. Discharge drains (into lower channel sections) can be used to hydraulically release these smolts below Wells. For other release sites, the smolts will have to be manually crowded and pumped. These should be good to high quality smolts. The probability of meeting mitigation goals is substantially higher than under present spawning channel technology.

Rocky Reach Annex/Turtle Rock Facilities: Rearing summer chinook and steelhead fry appears to be the optimum use of these facilities. (Chelan County PUD's original mitigation agreements were for fall Chinook. Coho salmon have recently been reared.) These facilities are best conceptually used in conjunction with Wells, where summer chinook and steelhead adult holding and spawning would take place. Depending on future ground water verification at Priest Rapids or at Turtle Rock, the chinook situation could change. Chinook spawning would occur at Wells and eyed eggs (about 1,895,000) would be transported to Rocky Reach Annex. Eight prefabricated raceways will be used for incubation and subsequent early fry rearing (November through March, possibly April). Their volume conceptually limits production at the Rocky Reach/Turtle Rock facilities. These raceways would use the good quality toe drain water; surplus quantities exist. From March to April, some 7,200 pounds of fry (1,800,000 fry) at about 250/pound would be transferred to replumbed Turtle Rock facilities. Ambient river water would be used to finish rearing the fry. Actual transfer should take place when river water temperatures are similar to toe drain water temperatures to avoid shock. Sufficient water flow exists so that fry could be temporarily held safely at the Annex at sizes larger than 250/pound. This should be avoided by cutting back rations during their early growth in subsequent years. Water temperatures as well as fry size (and subsequent loadings in the Annex raceways) should be considered to determine actual timing of transfer. By June, fry should have reached 40/pound, and 40,500 pounds (1,620,000 smolts) can be released. These should be high quality fry. This compares to the present mitigation goal of 500,000 fall chinook smolts.

Each of the Turtle Rock channel sections (4) is presently being replumbed to receive 15 cfs independent inflow. Sections 1, 2, and 3 would discharge below section 4 into the adult trapping section. Section 4 would discharge directly into the adult trapping section. The 60 cfs combined effluent would flow downstream through the existing channel. If sufficient ground water is verified, this 60 cfs flow (plus the ground water as a marker) would allow a sufficient flow for adults to orient themselves to this channel and use it to reach the trapping and sorting station. The adult trap and holding pond could be reactivated if some 15 to 20 cfs ground water is verified and available, and if temperatures are optimal. Fry could be released hydraulically to the river by the effluent system. They would have to be manually crowded and pumped or dipped if released elsewhere.

Steelhead adult holding, spawning, and early fry rearing could take place at Wells or at Chelan Falls Hatchery. Egg incubation can take place at the Rocky Reach Annex. This is discussed below. Fry (about 280,000) can be transferred to the Rocky Reach Annex raceways as soon as the summer chinook fry have been transferred to Turtle Rock and the Annex facilities have been cleaned. This should probably occur in March or April. Ground water temperatures at Wells or Chelan Falls should be similar to those at the Annex; Annex water temperatures at this season might be cooler. Fry will be reared in the eight prefabricated raceways into October. By then, they should have reached a size of about 20/pound. Some 270,000 fry (about 13,500 pounds) would then be transferred to Turtle Rock for final rearing. River temperatures should have dropped to about 60 degrees F and be similar to toe drain temperatures at this season. The Annex raceways would be cleaned after transfer and be ready to accept the eyed summer chinook salmon eggs.

Steelhead fry would be reared at Turtle Rock from October-November to about April (possibly May) when they should have achieved a size of about 6/pound. Some 40,500 pounds (243,000 smolts) production capacity is possible. Water volumes and temperatures will be good at both the Annex and Turtle Rock (in the seasons used). Good quality smolts should result.

Steelhead egg incubation can take place at the Rocky Reach Annex. About 6 cfs of surplus toe drain water is available for this. About 10 cfs is totally available. (Eight cfs were specified for total summer chinook early fry rearing. This could very safely be cut down to 4 cfs, resulting in only 1,800 pounds/cfs loading. Using 2 cfs would result in a loading of 3,600 lbs/cfs, which is still safe.) Vertical drip egg incubators from Wells could be installed to handle some 295,000 steelhead eggs. This would require 32 trays, 2 stacks of 16 each. Plumbing would be such that the top tray would incubate eggs. A small insulated and heated building would be required. Thus, only adult holding and spawning would have to take place at Chelan Falls or Wells. A total of 295,000 eyed steelhead eggs would be delivered to the Annex for incubation. Timing of spawning would have to be managed so that the swim-up fry stage occurs about April when the Annex raceways become available for early fry rearing. This alternative is logistically attractive.

Priest Rapids Facility: The optimum use of the Priest Rapids facilities is for fall chinook rearing by conventional vertical drip egg incubation and raceway nursery technology. The chief limitation to production capacity is water supply capability. Assuming 20 cfs of well water and 100 cfs of ambient river water are available, and using conservative raceway technology criteria, an instantaneous maximum loading of 396,000 pounds of actively feeding fry can be carried. At 40 fry per pound (the release size goal) this equals 15,840,000 juveniles. Assuming a conservative 90 percent survivorship, this requires an egg take of 17,600,000. This represents 3,520 females (at 5,000 eggs per female). Fewer males would be required to accomplish fertilization, but a 1:1 ratio is considered optimal. Thus, holding facilities for some 7,040 adults are needed.

Adult holding would take place in the existing adult holding pool and in the last six channel sections (after modification). The adult holding pool is designed for 25 cfs flow. At least 20 cfs of well water is available and additional river water can be blended in. Sections 19 through 24 of the channel would receive full remaining siphon flow of fresh river water (95 to 100 cfs). Gravels would be removed from all channel sections. A migration barrier would be placed at the head of Section 19.

If additional substantial amounts of well water are verified, these could be supplied to the lower sections by a header delivery system. (If substantial amounts are available, holding and spawning of summer chinook salmon should be considered here. The amount of holding capacity would have to be determined.)

Fish would be spawned and eggs incubated in expanded existing facilities. Fish trapping and handling facilities appear adequate. Forty additional stacks of incubation trays would be required in the incubation station; drains and main supply piping appear adequate. Internal plumbing additions would be required for water delivery to the new trays. Well water is preferred for egg incubation to accelerate incubation time. More than adequate well water appears to be available.

Well water supply pipe sizing to the incubation station, the adult holding pond, and the spawning channel needs to be reviewed. Temporary piping has apparently been installed to the incubation station and to the adult holding pool capable of providing at least 6 cfs of well water. This was part of the WPPSS mitigation settlement.

Slightly less than 17,600,000 initial fry must be accommodated. This is a large number and requires substantial space. A practical solution is to use sections 1, 3, 5, 7, 9, 11, 13, and 15 of the channel for early fry rearing. The entire channel would be replumbed so that sections 1 through 16 would have independent inflow and drainage. Gravels would be removed from all channel sections. Early fry would be reared solely on well water until they achieve a size of 250 fry per pound. Batches of swim-up fry would be placed in channel sections as they sequentially emerge. Temporary screens could be placed in these sections to accommodate further size separations if necessary. At 250 per pound, approximately 50 percent of the fry in sections 1, 3, 5, 7, 9, 11, 13, and 15 would be transferred to sections 2, 4, 6, 8, 10, 12, 14, and 16, respectively, by manually crowding them through a grated opening, resulting in direct hydraulic transfer. Just before transfer, river water would gradually be blended into each section over a period of a few days to acclimate the fry, especially to possible temperature differences from well water. At transfer, there would be 50 percent well water and 50 percent river water in sections 1 through 16. Flow would be about 2.5 cfs per section at transfer, and velocities would be about 0.02 fps.

Fry would complete their development in sections 1 through 16. Flow rates and velocities would gradually be increased by blending in more river water. Ultimately, each section would receive 7.5 cfs (1.25 cfs of which is well water) and velocities would be 0.06 fps. By May to June, fry should reach 40/pound and would be released as smolts.

Smolts from sections 1 through 15 would be hydraulically released into section 18 by the effluent system, and then to the river through the remaining channel sections. Smolts from section 16 would move directly through section 17 to 18, etc. If smolts are to be transported for release elsewhere, they would have to be manually crowded and pumped.

VI. DISCUSSION

Putting the area-wide fisheries mitigation requirements into one package dramatically increases ways to meet the requirements. Each PUD is no longer locked into doing the best job it could (in cooperation with the respective fisheries or game agency) with its facilities. Now we can address the facilities themselves and ask "What is the best potential use of this facility as is, and modified? What are the best collective uses of all the facilities?" It becomes obvious that some facilities have much greater potential for specific fisheries cultures than others. Individual facility missions could be reassigned accordingly. These reassigned missions follow:

Facility	Optimum Use
Washburn Island	Remain Inactive
Wells	Steelhead (plus Summer Chinook temporarily?)
Chelan Falls	Rainbow Trout
Rocky Reach/ Turtle Rock	Steelhead, Summer Chinook
Priest Rapids	Fall Chinook (plus Summer Chinook long term?)

Spawning channel technology here should be abandoned and be replaced by raceway nursery technology. Very high salmonid production can be accomplished at Priest Rapids and at Rocky Reach Annex/ Turtle Rock by judicious use of well water to accelerate egg incubation and early fry rearing and by then blending in (or going entirely to) river water to finish rearing the fry to release size. The production potential at Priest Rapids (396,000 pounds of chinook fry) is such that the entire chinook mitigation requirement (presently estimated at 116,000) could easily be handled there. Priest Rapids is the farthest downstream hatchery (in this section of the river), which would enhance smolt survival because the smolts would not have to pass four dams. Finally, the major user groups of chinook salmon (sports, commercial, and Indian) are all downstream of Priest Rapids, maximizing return on investments. Because of these factors, propagation of summer chinook should be considered at the Priest Rapids facility (perhaps 40 percent of the facility capacity should be considered for summer chinook). Additional summer chinook would be reared at Rocky Reach/Turtle Rock as planned. This would change the mission of Wells to steelhead entirely which should result in increased efficiencies there.

In summary, treating salmonid fisheries mitigation for several individual projects in the Mid-Columbia on a combined basis has many apparent advantages. We believe that similar benefits may result on other waterways that have multiple projects.

Potential Use of Hydroelectric Facilities for Manipulating the Fertility of Lake Mead[1]

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John R. Baker[3]

James E. Deacon[4]

Abstract.--Analysis of historical nutrient data for Lake Mead indicates that the fertility of the reservoir has decreased which may be the cause for a corresponding decline in the largemouth bass population. However, it appears that fertility can be manipulated by altering the operation of the dam. The depletion of nutrients in the euphotic zone by phytoplankton and subsequent accumulation in the hypolimnion during summer and fall provide a natural nutrient gradient from which water of varying fertility can be drawn for discharge. This combined with alterations in the depth or seasonal pattern of discharge can possibly be used to enhance fertility and bass production in Lake Mead.

INTRODUCTION

Reservoirs are usually highly productive aquatic systems during initial impoundment since nutrients derived from the basin provide adequate fertility for phytoplankton growth (Neel 1967). However, in deep-discharge reservoirs, nutrients that accumulate in the hypolimnion during thermal stratification are removed via the discharge. This progressive loss of nutrients tends to reduce the fertility of the reservoir and may explain why the productivity of deep reservoirs often decreases with time (Wright, 1967).

Analysis of historical nutrient data for Lake Mead, Arizona-Nevada indicates that the fertility of this large reservoir has decreas since 1956. Over this same period, the largemouth bass (*Micropterus salmoides*) population has undergone a significant decline (Espinosa Deacon and Simmons 1970, Allan and Romero 197 possibly due to this decrease in fertility. In this paper, we evaluate the relationship between fertility of Lake Mead and the operation of Hoover Dam, and suggest some mechanis whereby the fertility could possibly be manipulated to enhance productivity in the reservo

DESCRIPTION OF LAKE MEAD

Due to limitations imposed on length of papers for this symposium, the reader is referred to Hoffman and Jonez (1973) for a detailed description of Lake Mead. However, pe tinent morphometric characteristics of the reservoir are given in Table 1.

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[1] Paper presented at The Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

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able 1.--Morphometric characteristics of Lake Mead (derived from Lara and Sanders (1970), Hoffman and Jonez (1973))

Parameter	Lake Mead
aximum operating level (m)	374.0
aximum depth (m)	180.0
ean depth (m)	55.0
urface area (km^2)	660.0
olume (m^3 x 10^9)	36.0
aximum length (km)	183.0
aximum width (km)	28.0
oreline development	9.7
ischarge depth (m)	83.0
nual discharge (1977) (m^3 x 10^9)	9.3
orage ratio at maximum operating level (years)	3.9

DATA SOURCES

Nitrate data collected at the Hoover Dam ntake towers were obtained from the U.S. Geo- gical Survey "Quality of Surface Waters in e U.S.," Water Supply Papers 1946-1963 and om "Water Resources Data for Arizona" or ater Resources Data for Nevada," Water Qual- y Records 1964-1976 prepared jointly by the .S. Geological Survey and state agencies. cent nitrate and phosphate data were also tained from the Lake Mead Monitoring Pro- am.[5]

ISTORICAL CHANGES IN FERTILITY OF LAKE MEAD

The average nitrate concentration in the ilimnion and hypolimnion during thermal ratification (May to October) was computed om monthly measurements made at the Hoover m intake towers. Nitrate concentration in e epilimnion ranged from 200 - 350 µg·l^{-1} ring 1946-1952 but increased to 600 µg·l^{-1} the mid-1950's. (Fig. 1). Nitrate then creased sharply in 1957 but increased again ound 1960. After Lake Powell was formed 1963, nitrate concentration in the epilim- on increased slightly but decreased again ter 1969. The increase in nitrate con- ntration in the mid-1950's and early 1960's s caused by increased runoff and high trate loading from the Colorado River aulson and Baker 1979). Nitrate loading so increased during 1965-1969, but this was used by loss from Lake Powell rather than ooding from the Colorado River (Paulson and ker 1979). Subsequent to each increase in loading from the Colorado River, the nitrate concentration in Lake Mead had decreased within a few years. We are currently investigating the cause(s) for the decline in nitrate, but available data indicate that it is most related to the hypolimnion discharge at Hoover Dam.

The average nitrate concentration in the hypolimnion during thermal stratification always exceeds that in the epilimnion (Fig. 1).

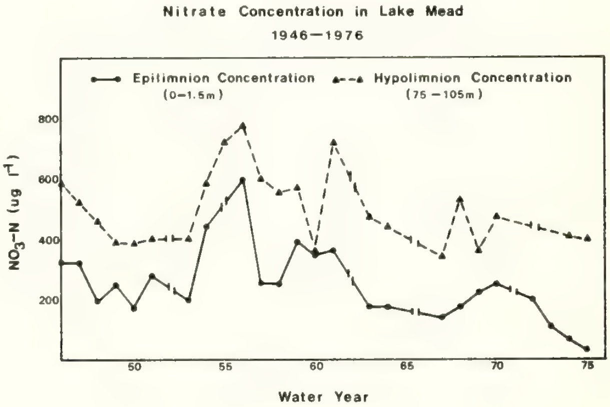

Figure 1.--Average nitrate concentration in the epilimnion and hypolimnion at the Hoover Dam intake towers during thermal stratification (May-October) 1946-1975. (USGS data).

This reflects the degree of nitrate accumulation that occurs either due to hypolimnion loading from the Colorado River or decomposition of morbid phytoplankton cells settling from the epilimnion. Periodic increases in hypolimnetic nitrate concentration (e.g. 1962, 1967) are apparently caused by hypolimnion loading. However, displacement of nitrogen from the epilimnion to the hypolimnion via sinking phytoplankton cells seems to be the principal mechanism of nitrate accumulation in the hypolimnion.

The concentrations of nitrate and phosphate in Boulder Basin of Lake Mead are essentially uniform with depth during the winter (Fig. 2). Epilimnetic nitrate, and to a lesser degree, phosphate, become depleted during the spring and early summer following periods of high phytoplankton productivity. By summer, nitrate has been reduced to less than 20 µg·l^{-1} in the euphotic zone with a corresponding accumulation of nitrate in the hypolimnion. Phosphate also accumulates somewhat but not to the degree observed for nitrate. As the lake mixes in the fall, the concentration of nitrate and phosphate becomes uniform and remains so through winter.

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[5] J.E. Deacon unpublished data.

The uptake of nutrients by phytoplankton in the euphotic zone and subsequent release and accumulation in the hypolimnion during the summer provide vertical and seasonal nutrient gradients from which water of varying fertility can be drawn for discharge. This combined with alterations in the depth or seasonal pattern of discharge represent potential mechanisms for manipulating the fertility of Lake Mead.

MECHANISMS FOR MANIPULATING FERTILITY

We have developed a simple model to illustrate how moving the discharge depth could influence the nutrient status of a reservoir (Paulson and Baker 1979). If water is discharged from the nutrient-poor epilimnion in the summer, the reservoir will accumulate nutrients, much like occurs in natural lakes. However, if water is discharged from the nutrient-rich hypolimnion, the reservoir will progressively lose nutrients. In a few years, this can have a significant impact on the fertility of the reservoir. The trends predicted by our model have been observed in experiments conducted on Kortowskie Lake, Poland under different discharge regimes (Mientki and Mlynska 1977). Annual nitrogen and phosphorus retention was 28% and -10%, respectively, for hypolimnion discharge but increased to 37% and 57%, respectively, for epilimnion discharge. Similarly, Martin and Arneson's (1978) limnological comparison of a surface-discharge lake and deep-discharge reservoir on the Madison River indicates that discharge depth can influence the nutrient status and productivity of these systems.

Alterations in the seasonal pattern of discharge from hydroelectric facilities can also influence the nutrient status of a reservoir, if seasonal nutrient gradients develop near the depth of discharge. In Lake Mead, nitrate concentration in the hypolimnion reaches a maximum in the late summer and fall. We have compared nitrate output from Hoover Dam from one year of relatively high seasonal discharge against a year of relatively low

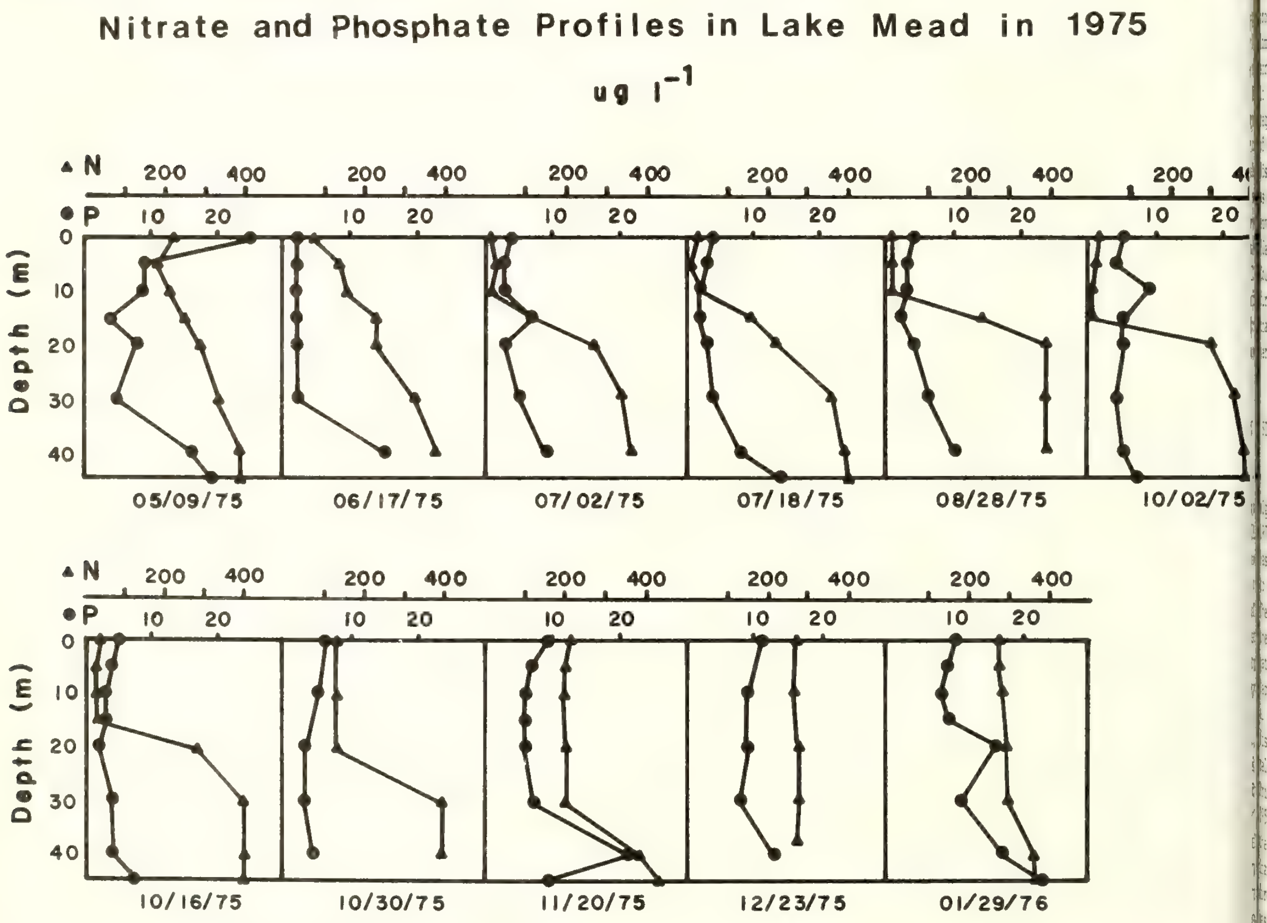

Figure 2.--Nutrient profiles in Boulder Basin, Lake Mead from May, 1975 to January, 1976 (Lake Mead Monitoring Program).

ischarge during the late summer and fall Paulson and Baker 1979). Annual nitrate loss as 15.0% higher during the year when discharge as high. Thus, it appears that the fertility f Lake Mead can be manipulated by altering he discharge regime at hydroelectric facilities. owever, there are other factors that must be nvestigated before this can be used for manage-ent purposes.

Alterations in the discharge depth can nfluence other physical and chemical factors. eservoirs with epilimnion discharge tend to issipate heat, whereas those with hypolimnion ischarge store heat (Wright 1967, Martin and rneson 1978). Oxygen concentration in the pilimnion does not vary appreciably with dis-harge depth, but oxygen in the hypolimnion is ypically lower with epilimnion discharge Stroud and Martin 1973). Altering the dis-harge depth can also have an immediate impact n limnological conditions of the river and eservoirs downstream. Enrichment of down-tream reservoirs is fairly common with hypo-imnion discharge (Neel 1967). The upper eaches of Lake Mohave, located immediately ownstream from Hoover Dam, are extremely roductive due to enrichment from the hypo-imnion of Lake Mead. Depending on the pre-cribed use of the downstream environments, t might not be possible to alter discharge egimes for purposes of nutrient manipulation f a reservoir. However, alterations in the ischarge of an upstream reservoir might prove s effective for managing the downstream nvironment as the reservoir itself. We have lentified several such possibilities on the olorado River system and are planning to rther investigate the potential use of dis-harge for environmental management of this eries of reservoirs.

IGNIFICANCE TO THE LARGEMOUTH BASS FISHING

Angler use on Lake Mead has increased gnificantly in recent years (Espinosa et al. 70). However, the total catch of largemouth ss has decreased from about 800,000 in 1963 the current level of 125,000 (NDFG 1977). e decline in the bass population has been e subject of much local concern and investi-tion. Arizona and Nevada Fish and Game partments are currently investigating sever- possible causes for the decline in the bass shery, but it appears that it could be lated to decreased fertility of the reservoir. ior to the high nitrate loading in the mid-50's, Jonez and Sumner (1954) suggested that e bass fishery could be improved by fertiliz-g Lake Mead. This has never been done rectly, although sewage input from Las Vegas s increased phosphorus input to Boulder sin of Lake Mead. However, the Colorado River provides most (80-90%) of the inorganic nitrogen (NO_3) to Lake Mead, and this has decreased in recent years (Paulson and Baker 1979). Without an additional nitrogen input, the phosphorus cannot be used efficiently by phytoplankton. However, it appears that more nitrogen could be retained in the reservoir by altering the depth or seasonal pattern of discharge. This might prove effective for increasing the productivity of Lake Mead. Since fish yield is closely related to plankton productivity and standing crop (McConnel 1963, Hrbacek 1969, Melack 1976), the largemouth bass population could be expected to increase if more nutrients were retained in the reservoir.

SUMMARY

The physical, chemical and biological processes that operate in reservoirs create vertical and seasonal nutrient gradients from which water of varying fertility can be drawn for discharge. This combined with alterations in the depth or seasonal pattern of discharge at the dam represent potential mechanisms for manipulating the fertility of the reservoir. By increasing the retention of limiting nutrients in the reservoir, the productivity could be expected to increase which, in turn, would sustain higher fish production. Thus, the operation of hydroelectric facilities may prove effective as a fisheries management tool in Lake Mead and other large reservoirs.

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A Case History — Unscheduled Fish and Wildlife Mitigation PL 93-320, Title I, Colorado River Basin Salinity Control Project [1]

F. Phillip Sharpe[2], Mildred Elkins[3], and Paul Strauss[4]

Abstract -- Subsequent to Project Authorization, Reclamation established Ad Hoc Commitees to develop an acceptable plan to mitigate habitat loss in Arizona and California resulting from the Colorado River Basin Salinity Control Act, while dealing with the sensitive issues of water scarcity endangered species, and state and national boundaries.

n 1961, the Republic of Mexico made formal rotest to the United States about the high alinity of the 1.5 million acre-feet a year f Colorado River water delivered to Mexico nder a 1944 Treaty.

n August 1973, after 12 years of sustained egotiations with Mexico and several interim easures, an agreement was signed by both ountries for a definitive and permanent olution to the river's salinity problem.

o implement this international agreement, the ongress in 1974 passed Public Law 93-320, the olorado River Basin Salinity Control Act. lthough not precluding the National Environental Policy Act, the Fish and Wildlife oordination Act, and other existing laws, his law did not specifically provide for fish nd wildlife mitigation, either in terms of dentified measures or in funding appropritions. One small exception in the area of unding was the existence of $300,000 for mitigating the habitat loss along the Coachella Canal. This money was a carryover from an earlier proposal for lining the canal.

Immediately after the passage of the Public Law, Reclamation was under tremendous pressure to complete the Environmental Impact Statement on Title I of the Act so Federal action could be taken as soon as possible in accordance with the international agreement. This Environmental Statement was not only to include project details and the environmental aspects of the project, but also fish and wildlife mitigation, heretofore left unaddressed. Suddenly mitigation became a critical item.

From the very beginning, the planning for this mitigation presented new challenges. For one thing, the water quality degradation (high salinity) which made the project necessary resulted from the use of a common water source by seven states. The project itself was located in two different states and Mexico; therefore, losses subject to mitigation are not found in just one state. Further complicating the issue is the international overtones resulting from the water treaty with Mexico.

In order to expedite the fish and wildlife planning process, Reclamation initiated the use of multiple discipline ad hoc committees composed of representatives from 11 entities including Reclamation, Fish and Wildlife Service, Arizona and California fish and game agencies, Bureau of Land Management, The State Department, three water user districts, and Arizona and California Colorado River water agencies. The charge given to the committees was to determine the habitat losses of the project and to develop alternative replacement measures in a timely fashion for inclusion in the final environmental statement.

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[1] Paper presented at the Mitigation ymposium, Fort Collins, Colorado, uly 6-20, 1979.

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It must be pointed out that during this same time, that is, between the time the public law was passed and signing of the final environmental statement, the details of the project features were also being developed. Needless to say, these tandem efforts meant a closer involvement between the project planners and the wildlife planners. The principle features of the project included three units; (1) replacing 49 miles of the unlined Coachella Canal in California to conserve 132,000 acre-feet/yr of water lost through seepage, (2) providing a well field along the United States-Mexican boundary capable of pumping 160,000 acre-ft/yr for delivery to Mexico for credit and other uses within the United States, and (3) the largest unit, constructing a 100 Mgal/d desalting plant capable of reclaiming 132,000 acre-ft/yr of highly saline agricultural drainage water.

It was obvious from the beginning that the project would cause wildlife habitat losses, and that some of this loss would be scarce riparian habitat. A major portion of the riparian habitat created by the Coachella Canal seepage would be lost. The well field would lower ground-water levels and habitat losses would be experienced along the agricultural drains and the Lower Colorado River. The desalting plant, which in itself would not cause habitat losses, required that saline agricultural drainage water previously discharged to the river below Morelos Dam now be discharged into a concrete lined channel, that will empty in Santa Clara slough in Mexico. As the drain water was in essence the only flow in the river below the Mexican diversion point, this action would cause the last 18 miles of the river within the United States to again become virtually dry and the attendant riparian vegetation would also be lost.

The first step for the committee was to get a determination on the vegetation types and associated wildlife affected and quantify the habitat that would be lost as a result of the project. The wildlife biologists from the committees' participating agencies organized and adopted a modified version of the Fish and Wildlife Service habitat evaluation procedures for this purpose. Project planning funds were transferred directly to the Fish and Wildlife Service and the two state agencies specifically for manpower to accomplish the task of evaluation. Although time was against them, a intense study was performed and credibl determinations were made. The committee found that 297 surface acres of open water an 5,200 acres of riparian vegetation would b lost, which constituted 12,157 habitat unit in California and 6,989 habitat units i Arizona.

The second step for the committee was t determine satisfactory habitat replacemen measures. A most difficult problem was tha all mitigation was required in a desert are and to construct new habitat requires water, scarce resource in the desert. Members of th committees suggested a wide variety of mitigation concepts and all concepts were considered. Those concepts that seemed to offe the most replacement potential were evaluate by the habitat evaluation procedures as wel as by legal, institutional, operational, ar management criteria. All this melded throug open discussion into a final listing of reasonable and satisfactory mitigation concepts These concepts were then set forth in th Project's Final Environmental Statement approved in June 1975.

Let's return briefly to 1974, when the critical planning of the mitigation took place Formal procedures did not then exist fo completing the consultation process describe in Section 7 of the Endangered Species Act The clearance process developed by Reclamatio for defining the net impacts of the Project o the endangered Yuma clapper rail was not to unlike the process now being used; that is Reclamation developed a comprehensive repo of the status of the rail, evaluated th anticipated impacts, and defined mitigatio and precautions that would be taken. Th resulted in a recommendation to the Fish an Wildlife Service. The Service conferred wit the State Fish and Game agencies and rendere a biological opinion that the project wou not affect the rail and its habitat to degree that would be critical to the surviva of the species.

During negotiations the question was raised to the need to mitigate the wildlife habita created as a result of seepage from the unlined Coachella Canal after its completion the late 40's. The Interior Field Solicit at Riverside, California ruled that mitigatio was required under the Fish and Wildli Coordination Act, even though the habita adjacent to the canal had been artificial treated.

The validity of the habitat evaluation metho and reports were challenged. An analysis o the procedures was made by a private a independent consultant which verified that the methods used and results obtained were valid.

The mitigation concepts developed by the Ad Hoc Committee were set forth in the Projects Final Environmental Statement approved in June 1975.

This, however, did not finish our work. Since the authorizing act was passed without provisions for mitigation or its funding, a project package had to be prepared for submittal to the Congress for reauthorization. Again we found ourselves with a critical deadline.

The obstacle to be crossed before a mitigation package could be presented to Congress was full agreement among the working parties that the mitigation features were satisfactory. This was accomplished by getting the directors of the Arizona and California game and fish agencies and the Fish and Wildlife Service to formally agree to the acceptance of the mitigation package before we went to Congress for reauthorization. This was done by endorsement of the ad hoc committees of the finished proposal. Then in good faith each state director and Fish and Wildlife Service signed a draft of an agreement which, after authorization, would be formalized into a final agreement.

To show that there can be results from all bureaucratic juggling, I would like to briefly discuss the final mitigation recommendations. There are six measures in Arizona that will provide a replacement of 66 percent of the losses. The costs in Arizona are estimated at $7 million. In California, five measures will be provided to replace 69 percent of the losses at an estimated cost of $3½ million.

The six measures recommended in Arizona are as follows:

. The Hunter's Hole measure is the mainteance of the existing Hunter's Hole Complex, ive miles north of the International Boundary ear Yuma, by installing a dike, with spillway nd drilling a well to maintain the water evel.

. Borrow Pit No. 2 will replace some of the ecreational fishing which will be lost. It s a borrow pit about 10 miles east of Yuma hich will be deepened and filled with water rom a well to be constructed to form an 8.4 cre pond for fishing and an intensively anaged area for wildlife and recreation.

, A warm water fish rearing station will be onstructed near Borrow Pit No. 2 for local tocking to compensate for lost angler days. These would be 16 one-half acre, clay-lined ponds maintained with the same source of water as that for Borrow Pit No. 2.

4. Gila River improvement is the placing of 6 sills in the shallow Gila River Pilot Channel, which carries irrigation return flows to the Colorado River. These sills would pond water upstream and form a series of pools downstream for increasing fish production.

5. Mumme Farm involves the purchase of 1,200 acres of land about 35 miles west of Phoenix for replacing riparian habitat. A mesquite bosque would be formed on 190 acres.

6. Prison Hill Wildlife Area will replace that most difficult of all things to replace in a desert--aquatic habitat. It will consist of excavating 40 acres of offstream ponds and backwaters near the confluence of the Gila and Colorado Rivers maintained by water from the Gila River Pilot Channel. The surrounding area will be planted with additional riparian habitat such as mesquite and willow trees.

The California measures would be similar.

1. Some 26 windmills will be installed along the first 49 miles of the newly-lined Coachella Canal to pump ground water and maintain selected sites of some of the habitat now being supported by canal seepage.

2. Approximately 360 acres of land near the Salton Sea will be purchased and turned over to the Salton Sea National Wildlife Refuge. This land will be improved by diking and grading into a series of open water areas for water fowl use and will be maintained by pumped irrigation and drain water.

3. Finney Lake restoration will consist of modifying and rehabilitating 40 acres of degraded marsh back to open water by the use of explosives.

4. Approximately 2,100 acres of selected parcels of land containing springs, ponds, and high quality desert habitat will be acquired and turned over to California Department of Fish and Game for management.

5. A 160-acre parcel of land will be purchased to expand Wister Unit Wildlife Management Area for the California Department of Fish and Game. The land will be graded and levees constructed to create additional marsh habitat.

In a brief summary there are several points which made the project interesting and unusual.

1. A provision for fish and wildlife mitigation was not included in the initial legislation.

2. There were the wide ranges of interest involved in this mitigation planning. The interests ranged all the way from the international to the private, local and Federal.

3. The coordination and logistics involved in using ad hoc committees to fully participate in the planning and evaluation of mitigation measures were immense.

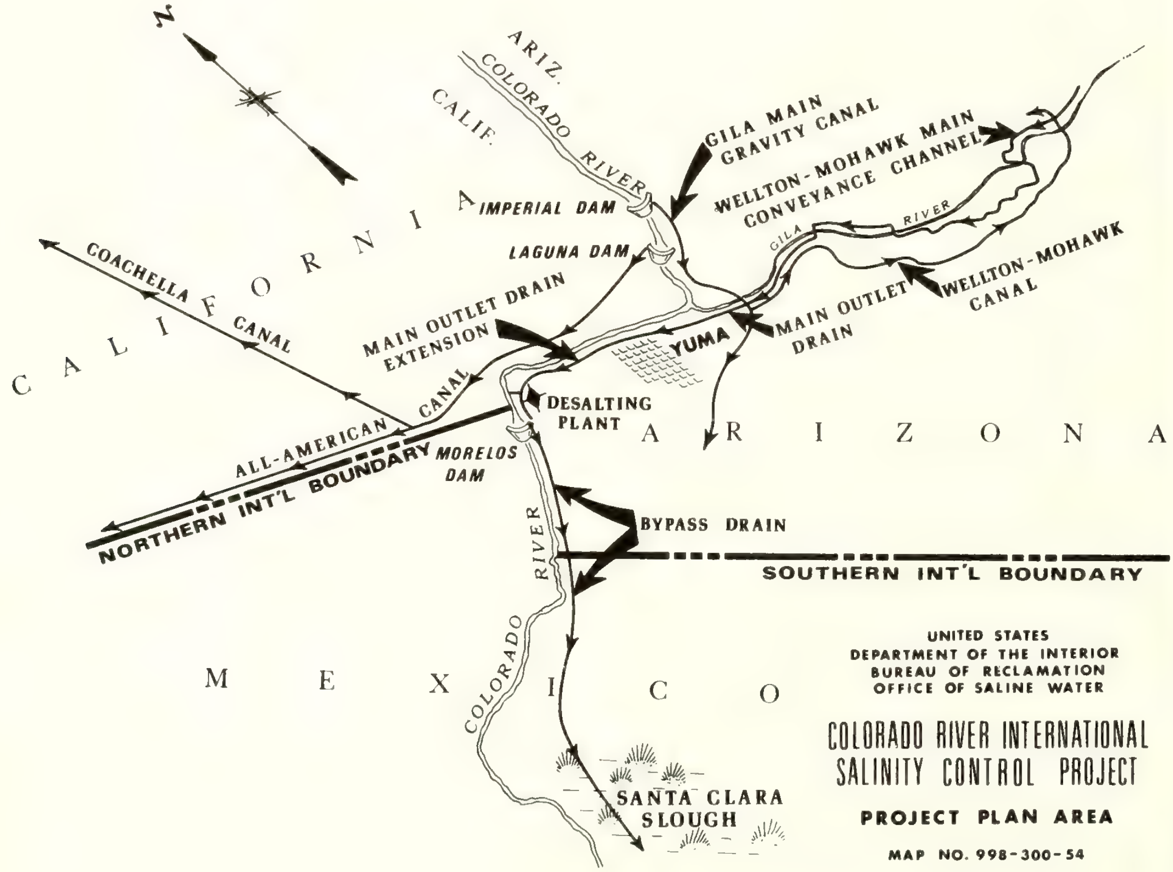
4. The presence of an endangered species lent an additional interest to this project.

5. An interesting, and possibly far-reaching, legal opinion came out of the mitigation planning when the Interior Field Solicitor's office stated that artifically created habitat created by seepage along the Coachella Main Canal did come under the preview of the Fish and Wildlife Coordination Act.

6. Habitat evaluation procedures used t identify resource values were reviewed an appraised for sufficiency by a private consulting firm when these procedures were challenged.

7. Complete concurrence was obtained fro all interested agencies, such as the Fish an Wildlife Service and the state fish and gam agencies before the final mitigation proposa was forwarded for approval.

We have received cooperation and help from al the parties involved. We are proud of th work we have done and we are doubly please that the States have agreed to manage an operate the projects once they are built. Th proposals have now gone forward to Congres for authorization and funding as part of th project package. Hopefully, we can report a the next conference that this mitigation i closer to becoming a reality.



Predicting Impacts of a Proposed Irrigation Water Conservation Project on Wildlife Habitat[1]

David E. Chalk[2]

Abstract.--Irrigation improvements on 84 percent of the treatable land in the Uintah Basin, Utah, could reduce water available to phreatophytes by 40 percent, resulting in the conversion of 19,800 acres of wetlands to upland habitat. Twenty-three percent of the water presently diverted for irrigation is consumed by phreatophytes. A 10.3 mg/l decrease in salinity will occur.

INTRODUCTION

The Colorado River Basin Salinity Control Act (Public Law 93-320) provides the authority for the U.S. Department of Agriculture (USDA) to participate, along with the U.S. Department of Interior (USDI) and the Environmental Protection Agency (EPA), in Colorado River Basin salinity control investigations. Title II (Section 203) directs the Secretary of the Interior to cooperate with the Secretary of Agriculture in carrying out research and demonstration projects and in implementing onfarm improvements and farm management practices and programs which will further the objectives of the Salinity Control Program on the Colorado River upstream of the Imperial Dam.

The Uintah Basin in Utah was one of the irrigation salt source control units being studied under the provisions of Title II. The USDA has formulated alternative plans for the Uintah Basin to improve onfarm irrigation efficiency, selected a recommended plan acceptable to the local people, and determined the effects of improved irrigation systems and management on salt loading to the Colorado River system. The U.S. Bureau of Reclamation (USBR) is studying the off-farm irrigation conveyance systems.

There are two main objectives for the USDA's participation in the salinity control studies: 1) To determine the present contribution to downstream salinity from irrigated cropland and related upland watershed areas; and 2) to determine the reduction in salinity that could be obtained by improving onfarm irrigation efficiencies and reducing erosion and sediment delivery from irrigated and upland areas.

An irrigation improvement plan for the Uintah Basin was selected from a combination of alternatives and calls for onfarm improvements to be installed on 84% of the potentially treatable land. The proposed program does not include treatment of about 16% of the irrigated areas because of poorly drained, highly saline wet areas. This will result in a projected decrease in salinity of 10.3 mg/l at Imperial Dam on the Colorado River. The implementation of the improvement plan is expected to have significant impacts on local wildlife in wetland and upland habitat. The purpose of the present study was to gather current wildlife habitat information so that the impacts of water conservation in the irrigated area on habitat could be analyzed.

DESCRIPTION OF THE STUDY AREA

The Uintah Basin Unit lies in the northeastern part of Utah and encompasses parts of Uintah, Duchesne, and Wasatch Counties. The Uintah Basin Salinity Study area is a large, diverse ecosystem. The variation in climatic conditions, elevations, and land use provides habitat for a variety of wildlife species.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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The Uintah Basin Unit consists of two major drainages, the Ashley Creek-Brush Creek drainage and the Duchesne River Drainage. The Duchesne River begins in the western part of the Uintah Mountains, flows southeasterly, and joins the Green River at Ouray, Utah. Its principal tributaries are the Strawberry River, Lake Fork Creek, and Uintah River. Ashley Creek and Brush Creek flow directly into the Green River near Jensen, Utah.

The 2,911,000 acres of land within the Uintah Basin Unit consist of:

National Forest Lands	1,219,000 acres
National Resource Lands	151,000 acres
Wildlife Refuge	12,000 acres
Private (Indian and non-Indian Lands)	1,471,000 acres
State Lands	58,000 acres
Total	2,911,000 acres

There are about 205,000 acres of privately owned irrigated cropland and pasture land of which about 21,000 acres are idle in any given year. The principal crops grown are improved pasture (46%), alfalfa (29%), salt-grass pasture (14%), small grains (6%), and corn for silage (5%). Livestock grazing occurs on nearly all of the land, including most wetlands, sometime during each year.

The average annual precipitation ranges from less than 7 inches near Ouray, Utah, to about 40 inches in the high mountains. The frost free period in the irrigated areas ranges from 115 to 125 days.

The Uintah Basin is a structural depression between the Uintah Mountains on the north and the Tavaputs Plateau on the south. The Uintah Mountains are the only major east-west mountain range in the Western Hemisphere. Elevations range from 4,655 feet at Ouray to about 13,500 feet.

The soils of the project area are derived from six different geological formations which strongly influence their productivity and physical characteristics. There is a lack of distinct horizons in the soil profiles. The low annual precipitation and resultant sparse vegetation have produced typical desert and semi-desert soils - low in organic matter and high in weatherable minerals and associated salts. The Roosevelt-Duchesne area soil survey was completed in 1940 by the Soil Conservation Service (SCS). A recheck of drainage and salinity conditions in 1954 showed an increase in saline area since 1940. A modern soil survey of Ashley Valley was completed in 1977.

Most of the soils have developed from marine shale formations. These soils are inherently salty and have a vast supply of salt. Current and past irrigation practices have resulted in water logging of soils in low-lying areas. This has caused a rapid increase in salinity, with many visible white salt accumulations on the surface.

The irrigation systems in the Uintah Basin are dependent on snowmelt runoff for the major portion of their water supply. The quantity of irrigation water varies from an excess during May and June to a deficit during the late summer. There are very few irrigation storage facilities to hold the runoff for later use, leading to overirrigatio during the early spring runoff period.

Irrigation is the major consumptive use of water in the Uintah Basin. Wetland and riparian vegetation and evaporation also consume large quantities of water. The arid nature of the climate, salt yielding soils, and evapotranspiration losses attributable to phreatophytic and hydrophytic vegetation associated with the wetlands all contribute to salt loading. The majority of the wetlands and some riparian habitats have been created by over-irrigation which causes a high water table and are directly dependent on this ground water for their continued existence.

Major wildlife species using the area included pheasant, mallard, red-tailed hawk, red-winged blackbird, mourning dove, muskrat, beaver, cottontail rabbit, jackrabbit, meadow vole, and mule deer.

STUDY METHODS

An onfarm wildlife inventory was conducte by the Utah Division of Wildlife Resources, under contract with the Soil Conservation Service. Several sample sites were establishe within each of nine evaluation units.

Riparian and wetland habitat areas in each evaluation unit were identified from existing maps prepared by the Utah Division of Water Resources (1971). Acreages were determined by planimeter and verified in the field. Wetland types were classified accordi to the U.S. Fish and Wildlife Service (USFWS) wetland classification system (Shaw and Fredine 1956). Representative areas within each type were classified in the field.

The evaluation of the habitat diversity was made using a technique developed by Thomas (1974) and Hamor (1974), modified for Utah. The process assumes that the diversity of wildlife species is directly related to the diversity of the physical habitat. The results are expressed in habitat values based on habitat diversity and quality criteria. The habitat values established for this study were for large areas and could vary at specific locations within an area.

There were 48,760 acres of the four major habitat types associated with these irrigated lands that are to some degree directly dependent on irrigation return flows:

Riverine or Riparian	16,295 acres
Greasewood, Saltcedar and Saltgrass (Type 1)	16,825 acres
Rushes and Cattails (Types 3,4,5,10, and 11)	2,215 acres
Grasses and Sedges (Type 2)	13,425 acres
Total	48,760 acres

Greasewood was evaluated along with the wetland types because this plant uses ground water like phreatophytes.

A water budget, or an accounting of water into and out of an area, was determined for each evaluation unit. This was done with the aid of an SCS computer model for irrigation analysis (IRRIGA), which computes monthly plant consumptive use by a modified Blaney-Criddle Method. The 14 year period, 1962 through 1975, was used to represent existing conditions and establish a base water supply. Canal diversion records were used to determine gross surface supply of onfarm water.

The IRRIGA model computed monthly and annual volumes of use from the watertable, net irrigation requirements, deficits, and excess water based on the information on irrigated acres, cropping patterns, water supply, irrigation efficiency, soils, and weather. The results were averaged to obtain average annual data for total water budgeting.

Ground water use by phreatophytes in each evaluation unit was based on a weighted average consumptive use. The acres of phreatophytes supported by onfarm irrigation return flows and canal seepage were assumed to be directly proportional to the volume of return flows from each source.

U.S. Geological Survey streamflow records were utilized to determine the average annual flow in the different river systems. These data were used in the water budgets of the entire Basin to determine the overall flow into and out of the two major drainages. The difference between the water in and the water out is the actual net depletion within the Uintah Basin. The consumptive use figures for phreatophytes were determined from actual data for the Ashley Creek area and additional information from the Sevier River Basin report (Table 1).

RESULTS

The four major habitat types were evaluated and average values determined for each type (Table 2). The scale used was 0 to 1.0 where 1.0 indicates that the habitat requirements of wildlife in the area could be satisfied on 100% of the area if conditions were optimum. The average value for riparian habitats was 0.59, greasewood-saltcedar-salt grass was 0.22, cattails and rushes was 0.61, and grasses-sedges was 0.32. The average habitat value for all irrigated land was established at 0.37. The average onfarm ditch habitat value was 0.33. Field observations

Table 1. Annual consumptive use of water by phreatophytes in the Uintah Basin, Utah.

Vegetation Type	Present Total (acres)	Depth to Water Table (inches)	Consumptive Use[1] (acre feet/acre)	Present Use (acre feet)	% of Total
Cottonwood-willows (riparian)	16,295	-	3.01	49,050	39
Cattail-rushes	2,215	-	4.07	9,010	7
Greasewood-saltcedar	4,900	0-12	3.77	18,470	15
Greasewood-saltcedar	4,575	12-36	2.09	9,560	8
Greasewood-saltcedar	7,350	36-60	0.78	5,730	5
Grasses-sedges	13,425	0-12	2.51	33,670	26
Total	48,760			125,520	100

[1] Normal consumptive use minus effective precipitation.

Table 2. Average habitat values for wetland and irrigated habitat types in the Uintah Basin, Utah.

Habitat Type	Depth to Water Table (inches)	Present Acres	Average Habitat Index Value
Cottonwood-willow (riparian)	-	16,295	0.58
Cattail bulrush	-	2,215	0.61
Greasewood-saltcedar	0-12	4,900	0.22
Greasewood-saltcedar	12-36	4,575	0.22
Greasewood-saltcedar	36-60	7,350	0.22
Grasses-sedges	0-12	13,425	0.32
Irrigated land	-	177,320	0.37
Onfarm ditches	-	4,980	0.33

indicated that onfarm distribution ditches do not offer much habitat diversity because most of them are grazed by livestock along with the fields. Chemical, mechanical, and fire control methods are used frequently to suppress vegetative growth along these canals and ditches.

The overall average irrigation efficiency for the study area was estimated to be 34%. The tailwater runoff and seepage from this low efficiency irrigation supplies nearly all the water in the wetlands and riparian areas in the entire unit. Significant reductions in the amount of irrigation runoff will impact these existing habitats.

Some progress in improving the existing irrigation conveyance systems, such as the installation of pipelines, concrete-lined ditches, and conversion to sprinklers, along with better irrigation water management is expected to occur in the future. There will be an overall reduction in the amount of water available to the phreatophytes as the irrigation efficiency improves. This loss of water will impact the various habitat types and locations within the evaluation units.

On-site determinations in each unit will have to be made in order to calculate the actual habitat losses by type associated with the predicted change in water availability. The percentage of the return flows is assumed to be proportional to water availability and all losses in habitat area are considered to be directly related to these percentages. Based on these assumptions, and the known percentage of water consumed by each existing habitat type, the impacted acres of each type can be predicted (Table 3). The consumptive use for present conditions and several alternative futures is displayed in Table 4.

DISCUSSION

Estimates of habitat losses as a result of implementing the selected plan to improve irrigation efficiency in the Uintah Basin are general rather than site specific. This analysis of habitat impacts assumed that the percentage of total water consumed by the phreatophytes and the actual return flows would remain constant under all alternatives. However, a reduction in flow may not necessarily reduce the water consumption by phreatophytes, i.e., these plants may consume what they need before there will be any excess water.

The selected plan to increase irrigation efficiency will consist of the installation of 79,400 acres of sprinkler systems and 42,800 acres of improved surface irrigation systems. This will have the net effect of increasing the overall irrigation efficiency from 34% to 51%, reducing the water available to existing wetlands by about 50,700 acre feet. The flow into the Green River will be increased by 20,200 acre feet and the salt concentration at Imperial Dam will be reduced by 10.3 mg/l.

MINIMIZING IMPACTS

Habitat losses associated with wetlands and related to reduced irrigation return flows indicate mitigation is needed. However, mitigating these losses may be a difficult task because salinity control and wetland preservation do not complement each other. Most wetland areas in the Uintah Basin do not function as natural wetlands because they are not associated with open water and the greatest wildlife use is by upland species. Replacement or improvement of upland habitat may have more overall benefits than replacing losses with wetlands.

Travel lanes and field borders could be planted and maintained for wildlife. Holding the use of pesticides to a minimum and leaving areas planted to small grain unharvested will benefit upland birds and mammals. Additional fencing and maintenance of unharvested cover area is recommended. Leaving a minimum of eight inches of residues at the end of the growing season will provide good winter cover for many species.

The greatest potential for mitigation of habitat losses lies with the individual farmers in the Basin. The development of conservation plans for individual farmers includes the identification of local site specific wildlife impacts and the determination of the techniques or practices required to improve wildlife habitat. The locations of specific improvements will be decided during planning.

The SCS encourages mitigation efforts, although landowner participation in any practice to improve wildlife habitat is voluntary. It would be highly desirable if legislative programs which specifically provide for funding or cost-sharing assistance for wildlife practices at the same rate as onfarm irrigation improvements would be implemented.

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Table 3. The impact of greater irrigation efficiency on habitat types in the Uintah Basin, Utah.

				Remaining Habitat by Alternatives				Selected Plan	
Habitat Type	Present Acres	Consumptive Use (acre feet/acre)	Present Use (acre feet)	Future Without Project Acres	Farmer Identified Improvement Acres	Potential Improvement Acres	Selected Plan Acres	Impacted Acres[1]	Value lost Acres[2]
Cottonwood-willow (riparian)	16,295	3.01	49,050	14,530	10,220	8,790	9,660	6,635	3,850
Cattails-bulrush	2,215	4.07	9,010	1,970	1,390	1,190	1,310	905	550
Greasewood-salt cedar water table 0 to 12"	4,900	3.77	18,470	4,370	3,070	2,640	2,900	2,000	440
Greasewood-salt cedar water table 12 to 36"	4,575	2.09	9,560	4,080	2,870	2,470	2,710	1,865	410
Greasewood-salt cedar water table 36 to 60"	7,350	0.78	5,730	6,550	4,610	3,960	4,360	2,990	660
Grass-sedge water table 0 to 12"	13,425	2.51	33,700	11,970	8,420	7,240	7,960	5,465	1,750
Total	48,760		125,520	43,470	30,580	26,290	28,900	19,860	7,660

[1] Present acres - Selected plan acres = Impacted acres.

[2] Lost as wetland habitat because of conversion to upland habitat.

Table 4. Consumptive uses of irrigation water under present conditions and for alternative futures, Uintah Basin, Utah.

	Water Budget				
Alternative	Onfarm Water Supply (acre feet)	Onfarm Irrigation Efficiency (%)	Consumptive Use Crops (acre feet)	Consumptive Use Phreatophytes (acre feet)	Return Flow (acre feet)
Present condition	549,200	34	287,500	125,500[1]	136,200
Future conditions without a project	526,400	40	301,300	108,400	116,700
Farmer identified irrigation improvements installed	494,600	50	330,600	78,800	85,200
Potential irrigation improvements installed	477,300	56	334,600	67,700	75,000
Selected plan	486,800	52	326,900	74,800[2]	85,100

[1] About 23 percent of the onfarm water supply is consumed by phreatophytes.

[2] The selected plan would reduce water use by phreatophytes by 40 percent.

Wetlands, Irrigation and Salinity Control: Lower Gunnison River Basin, Colorado [1]

Eldie W. Mustard[2] and Claudia D. Rector[3]

Abstract.--A total of 8,773 ha of wetlands was inventoried on a 72,800-ha area as part of an environmental assessment for a salinity control project in the Lower Gunnison River Basin, Colorado. Wetlands were evaluated for wildlife habitat value and use. Implementing measures to reduce salt loading to the Colorado River will cause wetland losses. Mitigation suggestions are given.

INTRODUCTION

The Colorado River Salinity Control Act (P.L. 93-320) was enacted by Congress in 1974 in response to downstream water users' concern over the increasing salinity in the Colorado River. This concern was voiced by Mexico and Lower Colorado River Basin states that depend on waters of the Colorado River for irrigation, industrial, domestic and recreation uses. Salinity, therefore, is both a national and an international problem.

Salt loading to the Colorado River comes from two primary sources: natural or geologic and man-caused salt loading from irrigation water conveyance systems and irrigated farming. Essentially, salts from saline soils are dissolved as water flows over the land surface or percolates through the soil profile and saline aquifers, eventually reaching the ground water and the Colorado River.

The Act instructed the Departments of Interior and Agriculture and the Environmental Protection Agency to carry out its objective: salinity control. It also identified specific areas, including the Lower Gunnison River Basin, where salt loading from water conveyance systems and on-farm irrigation was to be studied and ways to reduce it determined. The Bureau of Reclamation (BOR) and Soil Conservation Service (SCS) were designated by their respective departments to make these studies.

Briefly, the magnitude of salinity in the Colorado River is as follows. Measurements[4] at Imperial Dam in Arizona indicate that the Colorado River transports 6.3 million t of salt per year (BOR and SCS 1977). These salts come from many areas, including the Lower Gunnison River Basin which contributes over 1.0 million t per year. Studies in the Lower Gunnison River Basin have shown that on-farm irrigation contributes 240,000 t per year, with the remainder attributed to natural sources, major irrigation water conveyance systems, industrial and municipal sources.

Various ways to reduce salt loading contributed by irrigation include: lining or piping major canals and laterals, closing existing open drains, lining on-farm irrigation and tailwater ditches and improving the efficiency of irrigation water use on croplands. These practices, by decreasing the amount of water that seeps from conveyance systems or is applied to irrigated croplands, will reduce salt loading to the Colorado River.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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[4] Metric conversions are as follows:
1 metric ton (t) = 1.1 ton
1 hectare (ha) = 2.5 acre
1 kilometer (km) = 0.6 mile
1 meter (m) = 3.3 feet
1 centimeter (cm) = 0.4 inches
0.03 meter^3/sec (m^3/s) = 1 cubic foot/second (cfs)
Celsius temp. (°C) = 5/9 (F -32)
Fahrenheit temp. (°F) = 9/5 C + 32

Wetlands have been created by seepage from inefficient water delivery systems, drainage ditches and irrigated fields. These areas support a variety of native and exotic plants and animals, filling to some extent the void created when historic natural wetlands were drained or drastically altered in their conversion to other uses. Proposed water management improvements for salinity control will alter, reduce or destroy these irrigation-induced wetlands, displacing wildlife and plants.

The inventory and evaluation of wetlands in the Lower Gunnison River Basin, conducted under the direction of BOR, SCS and the University of Colorado was designed to assess the existing resource, and recommend ways to mitigate the adverse impacts of salinity reduction improvements on wetland habitat.

STUDY AREA DESCRIPTION

The 72,800-ha study area is in the Lower Gunnison River Basin of western Colorado and includes parts of Montrose and Delta counties. Boundaries of the study area are the Gunnison River on the north, the West Canal diversion on the south, the Selig and Loutzenhizer canals on the east, and the West and Montrose-Delta canals on the west (fig. 1).

This area is along the western flank of the Rocky Mountains with elevations ranging from 1,500 to 2,400 m. It is divided by the Uncompahgre River which flows from southeast to northwest with a gradient of 6.4 m/km. The Uncompahgre Valley, 50 km in length, ranges in width from several hundred meters at the West Canal to 3.3 km at its confluence with the Gunnison River. To the west is a series of mesas rising 120 m above the valley floor. Clayey hills, outcrops of saline Mancos Shale locally called "adobe", parallel the valley to the east, while the Grand Mesa overlooks the area from the north. Soils in the area vary from sandy loam riverbottoms to gravelly loam mesas to clayey adobe hills and are underlain with Mancos Shale.

The climate is typical of lower intermountain valleys of the West, with low annual precipitation (19.7 to 24.2 cm), low humidity, abundant sunshine and a wide range in annual and daily temperatures. Long-term temperatures have ranged from -32.7° to 41.1°C with a mean annual temperature of 9.9°C.

In 1881, following the resettlement of the Ute Indians in Utah, land in the Lower Gunnison River Basin became available for agricultural development. Low rainfall precluded dryland farming. Therefore, earthen irrigation canals were constructed from the Uncompahgre River to supply water to 4,250 ha of land. In 1909 additional land was brought under irrigation using 30 m^3/s of Gunnison River water diverted through the Gunnison Tunnel.

Currently, river flows, combined with storage reservoirs, provide a steady, high quality water supply through the 150-day growing season. Crops grown on the 40,000 ha under irrigation include corn, alfalfa, small grains, pinto beans, potatoes, onions, sunflowers and fruits.

STUDY METHODS

A complete description of study methods is found in Rector et al. (1979). The study was conducted in two phases. Phase I was an extensive inventory of wetlands that included 100 percent coverage of the eight major delivery canals and the Gunnison and Uncompahgre riverbottoms; a partial (45%) wetland inventory was made in the remaining area. Data were recorded by: location, U.S. Fish and Wildlife Service (FWS) wetland classification modified from Cowardin et al. (1976), canal or river name, vegetative cover and interspersion types adapted from Golet (1973, 1973a), soil series (Cline et al. 1967) and water pH or conductivity or soil pH.

The apparent source or sources of water supporting each wetland were identified: natural (river, stream, drainage), on-farm irrigation management, canal, or combinations of these three primary sources.

Inventoried wetlands were rated for their value as wildlife habitat using a system developed by Golet (1973, 1973a). Evaluation was based on water permanence, wetland class, size, class diversity, subclass diversity, location (bottomland, upland, lakeside, deltaic, streamside, isolated), surrounding habitat type, water and vegetation interspersion, vegetative interspersion, juxtaposition with other wetlands and water quality.

Wetlands were mapped and measured on aerial photographs. Wildlife, as well as dominant vegetation, were noted for each inventoried wetland.

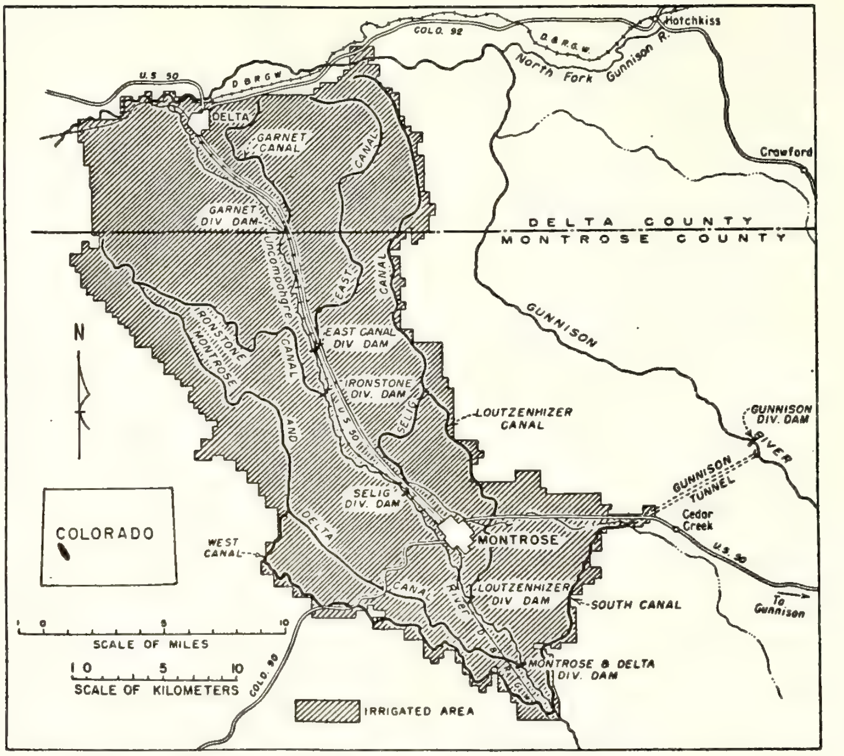

Figure 1.--Location and study area maps, Lower Gunnison River Basin, Colorado

Phase II was an intensive study on 30 selected wetland sites to sample plant, bird and small mammal populations. Wetlands were ranked according to use by plants, birds and mammals. Wetland use values were based on a summation of ratings for six parameters: small mammal numbers and diversity, large mammal observations, breeding bird density and diversity, and native plant condition.

The 30 selected sites were arbitrarily chosen to represent the four dominant FWS wetland types (forest, scrub/shrub, emergent-narrow-leaved and emergent/interspersed with water); principal water sources (natural, canal and irrigation management); and three general locations (east side of the Uncompahgre River, west side and riverbottom).

Bird censuses were after Emlen (1971, 1977) as modified by Franzreb (1977). Small mammals were trapped following a technique described by Calhoun (1948). Wildlife use values were compared to wildlife habitat values as adapted from Golet (1973, 1973a).

During Phase II a monitoring system was established which included installation of an engraved steel post bearing the wetland identification number and making a photographic record of each sample wetland. Vegetation maps were prepared for each sample wetland as part of the monitoring system.

RESULTS

Phase I - Extensive Assessment

Approximately 8,773 ha of wetland habitat were found in the 72,000-ha study area where wetlands ranged in size from 0.1 to 345 ha and averaged 11 ha. Wildlife habitat values for 804 wetlands ranged from 41 to 119 and averaged 78 on a scale of 41 to 123. Dominant FWS wetland types were: forest (40%), emergent/narrow-leaved (27%), scrub/shrub (9%) and emergent/interspersed with water (4%). Natural water sources were wholly or partially responsible for 80 percent of the wetland habitat, irrigation management to 37 percent and canals to 5.5 percent. Table 1 is a summary of the inventory data from Phase I.

Natural wetlands were found primarily along rivers and their tributaries and drainages. The presence of wetlands supported by canals and irrigation management appeared to be determined largely by the terrain and on-farm water management practices (open drains, tile drains, intercept drains, lined ditches, irrigation efficiency, etc.). Seepage from a canal or ditch constructed on a hillside frequently supported wetlands on the slope and valley below. Seepage from recessed water conveyance systems rarely supported wetland growth beyond the ditchbank.

Mean habitat values for wetlands supported by various water sources are given in Table 1. Natural wetlands and those supported in part by natural water sources consistently rated higher in habitat value than wetlands depending on canal water, on-farm irrigation water or combinations of these.

Phase II - Intensive Assessment

Biological inventories of the 30 sample wetlands indicated a high species diversity. A total of 123 bird species, 18 species of mammals and various reptiles and amphibians were observed. More than 80 plant species associated with wetlands were identified. Species observed are given in Rector et al. (1979). Wildlife use ratings ranged from 4 to 32 and averaged 18 on a scale of 0 to 50 (Table 2).

A direct correlation between habitat value ratings and wildlife use ratings was observed, with an overall correlation coefficient for individual sites of r = 0.6. Comparison of site means for these ratings by water source, wetland class and location resulted in correlation coefficients of r = 0.9 or greater.

When wetlands were compared by water source (fig. 2), natural wetlands had the highest wildlife use rating, followed by canal and on-farm irrigation wetlands. Comparison of the major FWS wetland types indicated emergent/interspersed with water wetlands were most valuable, followed by forest, scrub/ shrub and emergent/narrow-leaved (fig. 3). Wetlands located on river-bottoms rated higher than those east or west of the bottomlands (fig. 4).

Table 1.--Wetland inventory summary, Lower Gunnison River Basin, Colorado, 1977

Wetlands	No.	Total Hectares	Mean Size (ha)	Pct. of Total Wetland Area	Mean Habitat[1] Value Rating
BY WATER SOURCE					
Natural	207	5269	25.5	60.1	89
Irrigation Management	191	1342	7.0	15.3	70
Canal	92	153	1.7	1.7	71
Natural & Irrigation Management	203	1683	8.3	19.2	75
Natural & Canal	50	72	1.4	0.8	78
Natural & Irrigation Mgmt. & Canal	13	9	0.6	0.1	80
Irrigation Management & Canal	44	245	5.6	2.8	74
Total	800	8773	11.0	100.0	78
BY LOCATION[2]					
On-Farm	594	5405	9.1	61.6	76
South Canal	8	97	12.1	1.1	74
West Canal	22	24	1.1	0.3	76
Montrose & Delta Canal	60	35	0.6	0.4	79
Loutzenhizer Canal	10	5	0.5	0.1	71
Selig Canal	27	31	1.1	0.4	66
Ironstone Canal	24	35	1.5	0.4	77
East Canal	16	15	0.9	0.2	67
Garnet Canal	8	6	0.7	0.1	71
Gunnison River	9	1053	117.0	12.0	107
Uncompahgre River	22	2067	94.0	23.6	110
Total On-Farm	594	5405	9.1	61.6	76
Total Canal	175	248	1.4	2.8	73
Total River	31	3120	100.6	35.6	108
BY DOMINANT CLASS/SUBCLASS					
Forested - Broad-leaved deciduous	124	3478	28.0	39.6	93
Emergent - Narrow-leaved	300	2402	8.0	27.4	72
Shrub - Broad-leaved deciduous	165	962	5.8	8.6	80
Emergent - Interspersed with water	56	318	5.7	3.6	80
Flat - Vegetated	29	100	3.4	1.1	66

[1] Wildlife habitat value rating can range from 41-123: a wetland may receive 5 additional points for outstanding wildlife populations.

[2] A total of 270 wetlands were located "On-Farm" with 45% of the study area sampled. Number and area of on-farm wetlands were multiplied by a factor of 2.2 to estimate total on-farm wetlands based on extrapolation of sample data. All others are based on 100% samples.

Table 2.--Biological data for sample wetlands, Lower Gunnison River Basin, Colorado, 1978

Wetland Number	Wetland Class[1]	Dominant Water Source[2]	Location[3]	Size (ha)	Small Mammal Catch/180 Trapnights	No. Small Mammal Spp./Site	No. Spring Breeding Birds/ha	No. Spring Breeding Bird Spp./Site	Large Mammal Observation	Native Plant Condition[4]	Wildlife Habitat Value Rating[5]	Wildlife Use Rating[6]
507-555	Forest	Nat	R	33.9	9	3	14	20	X	3	113	23
548-477	Scrub/shrub	Can	W	0.7	3	2	23	10	0	3	78	13
549-537	Scrub/shrub	IM	E	3.5	8	3	12	11	0	3	72	15
549-538	Emergent/nl	IM	E	0.2	11	4	26	4	0	3	64	16
551-481	Emergent/nl	Can	W	2.0	4	3	27	11	0	3	72	15
555-489	Scrub/shrub	Can	W	8.0	9	3	21	19	X	3	90	24
560-564	Emergent/nl	Can	E	17.2	0	0	2	6	0	1	84	4
562-474	Forest	Can	W	4.4	2	2	27	21	X	3	111	21
574-510	Forest	IM	R	1.5	6	2	34	16	X	3	77	22
596-449	Emergent/nl	Can	W	4.9	0	0	4	11	0	3	76	8
607-542	Emergent/nl	IM	E	9.5	2	2	13	9	0	3	90	11
616-412	Forest	Can	W	2.4	4	3	31	14	X	5	100	24
619-582	Scrub/shrub	Can	E	6.7	6	2	31	16	0	3	88	17
628-589	Scrub/shrub	Nat	E	17.6	11	2	19	14	X	3	98	21
676-410	Scrub/shrub	Nat	W	78.6	7	1	8	26	X	3	105	22
703-388	Scrub/shrub	IM	W	2.2	5	2	21	14	0	3	86	15
754-455	Scrub/shrub	Nat	E	54.3	9	2	30	16	0	3	89	17
755-610	Scrub/shrub	IM	W	3.6	3	2	20	12	X	3	102	17
767-461	Scrub/shrub	Can	E	2.2	8	2	31	8	0	3	70	15
811-458	Emergent/nl	Can	E	42.0	1	1	1	4	0	3	80	8
812-612	Scrub/shrub	IM	R	3.0	13	3	15	17	X	3	98	29
813-395	Emergent/water	Nat	R	7.8	17	4	38	21	X	3	114	29
815-564	Emergent/nl	IM	W	1.6	7	3	10	2	0	1	55	9
852-601	Forest	Nat	R	46.8	2	1	14	15	X	3	118	17
864-479	Scrub/shrub	Nat	W	64.9	3	3	6	23	X	3	114	21
886-519	Emergent/nl	IM	W	0.2	4	2	43	3	0	1	55	11
886-539	Forest	IM	W	0.2	4	2	75	4	0	1	70	15
921-591	Emergent/water	Nat	E	5.6	23	3	32	18	X	3	102	29
922-506	Emergent/nl	Nat	W	15.7	9	2	10	23	X	3	90	22
938-570	Emergent/water	Nat	R	11.0	30	4	32	11	X	3	115	32

[1] USFWS classification (Cowardin et al. 1976).
[2] Natural, Canal, Irrigation Management.
[3] East of Uncompahgre River, West of Uncompahgre River, R'verbottom of Uncompahgre or Gunnison rivers.
[4] Wetland rating based on presence and dominance of native plant species relative to weedy species.
[5] Ratings after Golet (1973, 1973a).
[6] Rating can range from 0-50.

WETLAND LOSSES - PAST AND POTENTIAL

Historically the major rivers in the Lower Gunnison River Basin are thought to have supported 4,690[5] ha of wetlands of which 3,120 ha remain; a loss of about 33 percent. Most of the lost wetlands were converted into cropland, while the wildlife values of those remaining are decreasing because they are subjected to a variety of other uses.

A total of 8,773 ha of wetlands was inventoried in this study, with wetlands supported by natural water sources comprising 60 percent or 5,264 ha. We do not believe that salinity control activities will adversely impact natural wetlands. However, landusers may decide, without project assistance, to convert some of these wetlands to cropland, irrigating them with water saved by more efficient water management.

The remaining 40 percent (3,509 ha) could be destroyed or altered if salinity control measures were fully implemented. These are irrigation-induced wetlands, supported totally or partially by irrigated agriculture using the 30 m^3/s of Gunnison River water that is diverted into the Uncompahgre Valley. Wetland losses would result from concrete lining or piping canals, laterals and on-farm ditches; closing and piping open drains; improved irrigation water use efficiency and other improvements.

Actual project-caused wetland losses cannot be calculated until various alternatives are considered. Economic considerations suggest that something less than total project implementation may occur.

Regardless of degree of implementation, there will be wetland losses. Salinity control efforts and maintenance of wetlands now existing in the Lower Gunnison Basin will often be incompatible; choices and compromises will have to be made.

DISCUSSION

Mitigation is both a concept and an act. Typically it has meant replacement, but it can include minimizing adverse impacts and enhancing remaining wildlife habitat to increase the per unit habitat value. With this in mind, the following suggestions are made for mitigating wetland losses in the Lower Gunnison River Basin.

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[5] The total of Alluvial, Wet Alluvial, Saline Wetland and Uncompahgre soils (Cline et al. 1967), all wet soils lying adjacent to the rivers and supporting hydrophytic growth in their natural state.

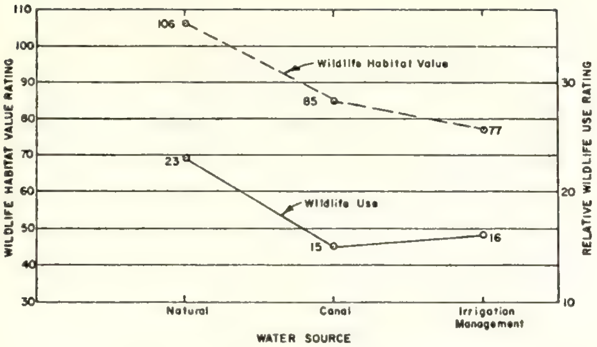

Figure 2.--Comparison of means for wildlife habitat value and wildlife use rating, by water source, from 30 intensively studied wetlands, Lower Gunnison River Basin, Colorado, 1978

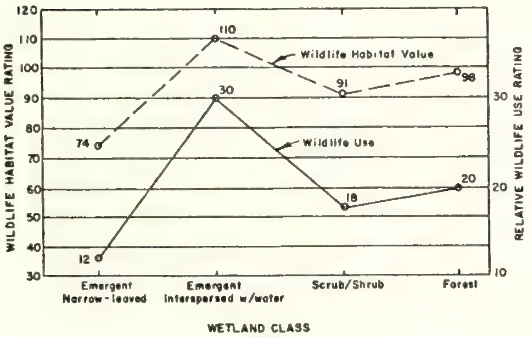

Figure 3.--Comparison of means for wildlife habitat value and wildlife use rating, by wetland class, from 30 intensively studied wetlands, Lower Gunnison River Basin, Colorado, 1978

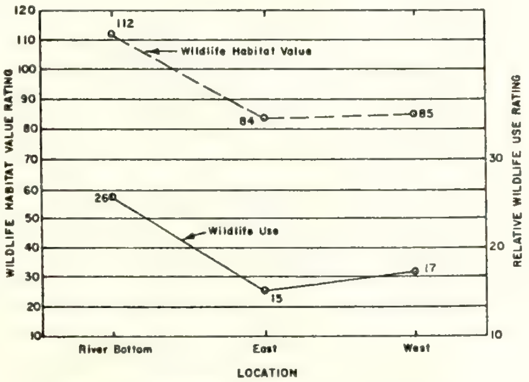

Figure 4.--Comparison of means for wildlife habitat value and wildlife use rating, by location, from 30 intensively studied wetlands, Lower Gunnison River Basin, Colorado, 1978

Minimize Impacts

Salinity control efforts could be restricted to only those areas that contribute the greatest salt loading. For instance, for planning purposes SCS has divided the basin into units or watersheds and is determining the salt loading inputs from each. Preliminary data indicate that one 7,322 ha area produces 43,200 t per year or 18 percent of the total salt loading attributed to irrigated agriculture in the basin. Another opportunity to minimize impacts would be to implement salinity control efforts only on the east side of the Uncompahgre River which contributes the majority of the total salt loading and has fewer kilometers of canals, laterals and irrigation ditches than the west side. Wetlands on the east side of the river are generally less valuable than those found on the west.

Wetland losses could also be minimized by designating those wetlands that are most valuable, where disturbance should be a last resort. These include wetlands adjacent to the rivers and some found along the West and Montrose-Delta canals on the west side of the Uncompahgre River.

Replacement

Wetland losses should be replaced in the vicinity, where possible. In salinity control efforts this may be impractical because wet areas removed in the name of salinity control may be replaced with nearby wetlands that may have the same salt loading potential.

Some on-site habitat replacement is possible, but not necessarily with wetlands. However, many upland wildlife species freely associate with wetlands so replacement of some wetland habitat with upland habitat is not as radical a departure as one might think.

Field border plantings could be made on individual farms. Plant species that most nearly replace those found in our wetlands could be used. SCS irrigation specialists indicate that about 25 percent of the water put on a field with a furrow irrigation system leaves the field as tailwater runoff. This creates wet areas at the lower ends of fields which adds to salt loading when these tailwaters percolate into the ground water. This percolation could be partially controlled by planting phreatophytic plant species which would remove excess water by evapotranspiration. It is also a non-structural way of taking care of excess water which would benefit wildlife much more than a concrete lined tailwater ditch.

Off-site replacement, i.e., replacement outside of the Lower Gunnison Basin, is a possibility. We consider this a last resort approach to mitigation; however, it may be a feasible mitigation alternative if others aren't acceptable or can't be accomplished.

Enhancement

Thirty-six percent of the inventoried wetland area is located adjacent to the Gunnison and Uncompahgre rivers. As previously indicated, it is doubtful that these will be adversely affected by salinity control measure implementation. They were the highest in both wildlife habitat value and use. These wetlands, with enhancement, could furnish adequate habitat unit values to mitigate probable wetland losses along canals and laterals and on farms.

There are several advantages to enhancing riverbottom wetlands to compensate for other wetland losses:

- It would protect floodplain and riparian habitat from further development and encroachment; these are national and state goals.
- They are currently highly diversified and productive wildlife habitat.
- Their high habitat values indicate that fewer hectares would be needed to compensate for losses of less valuable canal and on-farm wetlands.
- They would not add to the salt loading problem.
- Their habitat potential could be realized rapidly; livestock grazing control and management alone would be highly beneficial and yield relatively rapid results.
- Acquisition or other means, such as conservation easements to obtain use for wildlife, could be accomplished on contiguous areas which would enhance management opportunities and potentials.
- They are centrally located in the area where project-caused wetland losses will be incurred, thus precluding need for mitigation outside the project area.

There are some problems associated with acquiring and enhancing riverbottom habitat. Among them are:

- Removal of private land from the tax base is not popular in many Colorado counties where a high percentage of land is already in public ownership. (Use of conservation easements would placate this; taxes are paid on land under easement).
- Landowner may be reluctant to sell or give a wildlife use easement via the conservation easement route.
- Landowner may not want to sell or give an easement on just the riverbottom portion of his property; it may mean acquiring a whole farm or nothing and this could be costly.
- Concentration of wildlife habitat in fewer areas will decrease wildlife habitat dispersal in the basin.

RECOMMENDATION

We realize that final mitigation decisions will come after an interagency habitat evaluation is made. However, in an attempt to assist the decision makers, we propose that mitigation be centered on enhancement and acquisition of perpetual wildlife use rights along the riverbottoms together with habitat replacement or enhancement as can be obtained on individual farms. The need for extensive mitigation can be greatly reduced if efforts are made to take advantage of apparent opportunities to minimize project-caused wetland losses by selecting for treatment those areas that contribute most to the salinity problem in the Colorado River. This latter suggestion is highly appropriate from both an economic and an environmental viewpoint.

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Restoration of Wildlife Habitat to Offset Project Losses, Garrison Diversion Unit, North Dakota[1]

Allyn J. Sapa[2]

Abstract.--The paper discusses the Fish and Wildlife Service development of a restoration wildlife plan to replace wetland and grassland habitat losses resulting from the construction of the Garrison Diversion Unit, N.D. Primary emphasis of this plan is maintenance of the habitat base by restoring 1 acre of habitat for each acre of any habitat lost due to project construction.

Today I will describe for you a wildlife plan featuring habitat restoration. This plan is designed to offset habitat losses occurring from construction of the Garrison Diversion Unit project in North Dakota.

Restoration itself is not a new concept to the biologist, particularly in the pothole country of North Dakota. Service biologists have been plugging ditches and seeding grasses for many years. The soils and climate of the prairies, where wetlands and grasslands are the dominant types, allow a relatively quick response to restoration efforts. Restoration is, however, a new approach when applied on the large scale necessary to offset extensive losses from a major irrigation project.

Basically, the Service's intent is quite simple--maintain the habitat base by restoring as much habitat as will be destroyed by the project.

I will explain how this concept will work, but first I think it is necessary to describe some of the background from which this proposal evolved.

The area which the project will influence is distinctively known as the Prairie Pothole Region. The North Dakota portion of this region is part of a large geologic area which generally encompasses the southern portion of the Canadian prairies, western Minnesota, and the eastern half of North and South Dakota. Over 10,000 years ago, the great ice sheet of the Wisconsin glacier receded from this land, leaving behind countless shallow depressions capable of holding water.

Tallgrass prairie and mixed grass prairie plant communities were prevalent throughout the pothole region of North Dakota. These pristine grasslands occurred in combination with complexes of natural wetlands to form a dynamic ecosystem, supporting countless thousands of migratory birds and resident animals.

The two main land forms in the prairie wetland country of North Dakota are the Missouri Coteau and the Drift Plain. The Coteau is a rolling land form approximately 30 miles wide and parallel to the Missouri River. The Coteau generally contains well defined, relatively permanent wetland basins of all sizes, shapes and depths. The Drift Plain, like the Coteau, possesses an abundance of wetland basins, but has a flat landscape with little relief. Wetlands of the Drift Plain are more subject to drought than the Coteau and, depending on winter snowfall and spring runoff, offer a "bust or boom" to waterfowl production.

Since settlement of North Dakota, the prairie has undergone considerable changes. Soils developed under prairie are inherently fertile; because of this, many of the prairie wetlands and native grasslands in eastern North Dakota have been converted to agricultural use.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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The Garrison Diversion Unit is a multipurpose Federal water project being constructed by the Bureau of Reclamation in central and eastern North Dakota. Primary purposes of the authorized project are to irrigate 250,000 acres, provide for fish and wildlife conservation, municipal and industrial water, recreation, and flood control.

The project was authorized in 1965, with construction beginning in 1967. Basically, the plan proposes to lift and divert Missouri River water impounded in Lake Sakakawea, through Lake Audubon, into the McClusky Canal. This water will flow 73.4 miles by gravity into the Sheyenne River basin, to be impounded by the Lonetree Reservoir. Water will be distributed from this regulatory reservoir north, east, and south by gravity flow for project purposes.

The project requires construction of four major canals, and development and utilization of four major reservoirs. In total, 187 miles of open canal, 495 miles of pipe, and an undetermined number of wasteways will form the basis of the distribution systems; in addition, 327 miles of open drains and 1,723 miles of pipe drains will be required to remove return flows from the irrigated lands. Three major river systems will convey irrigation or return flows.

When we superimpose the Garrison development on the wetland/grassland ecosystems of the prairie pothole country of North Dakota, there will be substantial impacts to fish and wildlife habitats. Some of the most extensive remaining grassland/wetland habitat in eastern North Dakota will be destroyed.

We have identified impacts to a number of habitats. Basically, adverse impacts can be placed into three groups--habitats that will be lost, habitats that will be degraded, and impacts to habitat that have not been quantified due to technical problems or incomplete data.

Wetlands will be the most extensive habitat adversely impacted. Some will be inundated by reservoirs, others will be drained and filled by canals or tile drained to facilitate irrigation, while still others will be degraded by water quantity changes.

Native and tame grasslands and woodlands will be inundated by reservoirs, or converted to cropland.

Loss of some wetland and grassland habitats, in addition to having a significant impact on fish and wildlife resources, will remove beneficial physical characteristics such as flood control, nutrient removal, and ground water recharge potentials.

To facilitate flows, rivers and streams will be channelized, their flow regimes will be modified, and they will be subjected to quality and quantity modifications. The project distribution system will connect most rivers and streams in the eastern half of the state, thus allowing an avenue for movement of undesirable fish species into sport fisheries and waterfowl habitats.

In addition to adverse project impacts, there is a potential for fish and wildlife values on project rights-of-way. With proper management, it is projected that fisheries will be established and maintained in the project's regulatory reservoir and canal lakes. Also, upland right-of-way, if managed for wildlife purposes, would be useful for some wildlife species.

However, analysis of the overall project indicates that there will be extensive adverse impacts to fish and wildlife resources. The problem, then, for the biologist is to quantify the impacts and determine how they might best be offset.

In 1965, the project's authorization included a wildlife plan featuring waterfowl management and fishery development on 146,530 acres. There were 36 major areas, averaging about 3,900 acres in size. Project water supply was the major criterion used in selection of the area; therefore, most of the areas were located adjacent to or near supply features. Basically, the plan proposed to add project water to deepen and expand existing marshes and lakes. This would increase the surface acres of water in an attempt to replace wetland habitat losses and create fishery enhancement. By applying recent research knowledge, we now know this plan would not accomplish the project's wildlife objectives.

Project details released in the project's final environmental impact statement in the early seventies prompted the Service to begin a reanalysis of the project and its impact on fish and wildlife resources. At the same time, we conducted a literature review to develop a representative technical base to propose a modification of the project's wildlife plan. This was done in 1974 with the report entitled "Reevaluation of Fish and Wildlife Areas As Related to the Garrison Diversion Unit." It was this technical base that set the stage for development of the restoration plan.

Between 1974 and 1977, all irrigation areas and major project features were reinventoried to more accurately quantify existing habitat.

This confirmed that wetland and grassland habitat losses associated with the project had been underestimated. Results of our reanalysis indicated that 146,342 acres of wetland (including 70,910 acres on National Wildlife Refuges) would be lost or adversely affected. In addition, 66,639 acres of grassland and 4,046 acres of woodland would be lost. To facilitate flows, 142 miles of stream would require channelization. We also identified other impacts that presently could not be quantified. Some of these impacts include introduction of rough fish into waterfowl habitat, interbasin transfer of fish species, channelization, impacts to endangered species, and increased avian disease potentials.

The recognition of the magnitude and scope of wildlife habitat losses, particularly losses to National Wildlife Refuges, strengthened the Service's desire to develop a new approach to the wildlife plan. The magnitude of these habitat losses required that the Service select a wildlife plan which would provide the maximum gain in wildlife habitat per unit of acquisition.

Several assumptions were made when we began formulating changes to the wildlife plan. Since wetlands would be the largest habitat group affected, we determined that this habitat should be the focal point of any modification. We also decided to analyze modifications that would utilize or manage, as much as possible, the natural dynamics of the Prairie Pothole Region to accomplish project goals. We knew, for example, that: (a) the pothole system had evolved over thousands of years of alternate dry and wet periods; (b) that complexes of wetlands of different types have more value to wildlife than monotypic deep marshes; (c) that maintaining artificially high water levels and changing water quality are likely to result in loss of habitat for other species. There was also a desire to consider nonwildlife values such as flood control, nutrient removal, and ground water recharge. Grassland restoration features of the plan would complement all of these assumptions.

The conclusion of our analysis was that maintenance of the habitat base, at least for those quantified losses, would be required if we were to adequately mitigate fish and wildlife losses of the Garrison project. This could best be accomplished by restoring some of the thousands of acres of wetlands and grassland habitats previously destroyed. Thus, the restoration concept was born.

The restoration plan emphasizes reestablishing natural wetland complexes interspersed within blocks of upland cover. Restoration of these habitats which had been drained or plowed years ago essentially recreates high quality wildlife habitat where none currently exists, rather than replacing one type of habitat with another.

Service biologists knew that natural wetlands presently drained could easily and inexpensively be restored. The Service, through the years, has gained valuable and extensive experience in the management of natural wetland complexes, primarily through its administration of the Small Wetlands Acquisition Program. Some of the areas acquired for this program contain cropland and drained wetlands which have now been successfully restored. Drained wetlands can be simply and inexpensively restored by filling in portions of the drainage ditches. Once this is accomplished, aquatic vegetation returns almost immediately. Tilled lands are generally seeded with tame and native grasses to reestablish grassland communities. It was based on this experience that the Service confidently embarked on the restoration plan.

In developing the plan, a number of improvements over the original plan were recognized. The new restoration plan places emphasis on prairie wetland restoration with water supply from natural runoff rather than from constructed works. Funds will be dedicated to quality land acquisition, with deemphasis on construction and operation and maintenance costs. Widespread alternative sites are available within the total area (25-county Conservancy District). The average size of the new wildlife areas will be approximately 300 acres, which will reduce landowner displacement. Smaller tracts over a wider area mean a greater dispersal of areas and therefore greater public accessibility. Finally, wetland restoration returns habitat for natural biotic communities, considering all wildlife species.

This plan is based on the assumption that wildlife plan acres will be acquired concurrently with other project features. Title to all single purpose wildlife lands acquired will be vested in the United States, with the U.S. Fish and Wildlife Service assuming primary jurisdiction for management responsibility. The North Dakota Game and Fish Department will manage lands by agreement with the Service.

Once the basic concepts were established, a discussion of the plan and representative areas were provided to the appropriate agencies and congressional committees for approval and sanction.

That very basically describes the habitat restoration plan for the Garrison Diversion Unit. There are many factors yet to be worked out. Among them are the local and political forces which are shaping the project.

Implementation of this wildlife plan will have a significant impact on wildlife resources, not only in North Dakota, but also nationwide. Failure to implement the plan would result in a severe reduction in wildlife habitat in the Prairie Pothole Region. Failure could also affect future wildlife plans or projects which might require restoration as a mitigation proposal. The restoration of wildlife habitat can be the tool that makes this and other water development projects more environmentally acceptable.

New Opportunities on the Horizon[1]

Keith D. Bayha[2]

Abstract.--A recent multi-agency study proposed a National Water Conservation Program for the irrigation sector. Improved instream flows, freshwater inflows to estuaries, and water quality are among the identified beneficiaries. Timely participation by fish and wildlife agencies is essential to seizing this opportunity to mitigate past losses of stream habitat.

President Carter in his Water Policy Message of June 6, 1978, and his subsequent water policy directives (July 12, 1978) has given high visability to the necessity of implementing water conservation programs and providing for instream flows. The Second National Water Assessment (WRC 1978) documents, on a gross scale, the relative instream flow conditions and the competition for water. It showed that nation-wide irrigation accounted for 47 percent of the total water withdrawals and 81 percent of the consumption. In the west these ratios are even higher.

All this merely tells us what most already knew - that many streams are already seriously depleted.

The President's Instream Flow Task Force has recently assembled a list of Federal projects where improvements could be made (Subgroup E of the Instream Flows Working Group 1979). A more intensive inventory of instream flow conditions is currently under way. It provides an indication of the extent of this problem in those states where input has been elicited from Fish and Wildlife Service/Ecological Services personnel (fig. 1).

So what? you ask -- For most of these stream reaches there is no water with which to correct the effects of past decisions. Consider this! Responding to a series of GAO audits, a multi-agency study was conducted in 1978 by USDA-USDI-EPA which offers new hope! The results of this study have just been released (Interagency Task Force on Irrigation Efficiencies 1979).

My purpose here on this program is to call your attention to this report and the new opportunities it offers for correcting some of our past abuses of streams -- i.e., MITIGATION

This report, entitled "Irrigation Water Use and Management" contains chapters which:

Chapter 1. Characterize irrigation's development, significance, use of water and land, geographical diversity, and the various settings with attendant methods and economics.

Chapter 2. Covers water law and institutional aspects -- provides a well written description of surface and ground water law; rights to return flow; water administration; abandonment and forfeiture; compacts, decrees and treaties; local institutions; the Federal role; and the implication of water conservation within the appropriation doctrine.

Chapter 3. Describes existing state and Federal programs.

Chapter 4. Discussion of actions affecting irrigation efficiency, results of inefficiency and problems of data collection.

Chapter 5. Outlines available measures for improving efficiency with associated costs and impacts.

Chapter 6. Discusses the acceleration of irrigation in the humid eastern states and forewarns of impacts and the trend toward adoption of the appropriation doctrine.

Chapter 7. Outlines a proposed approach for implementing a "Water Conservation Program."

Like that report, the previous speakers on this panel have discussed some of the complexities involved in considering the trade-offs

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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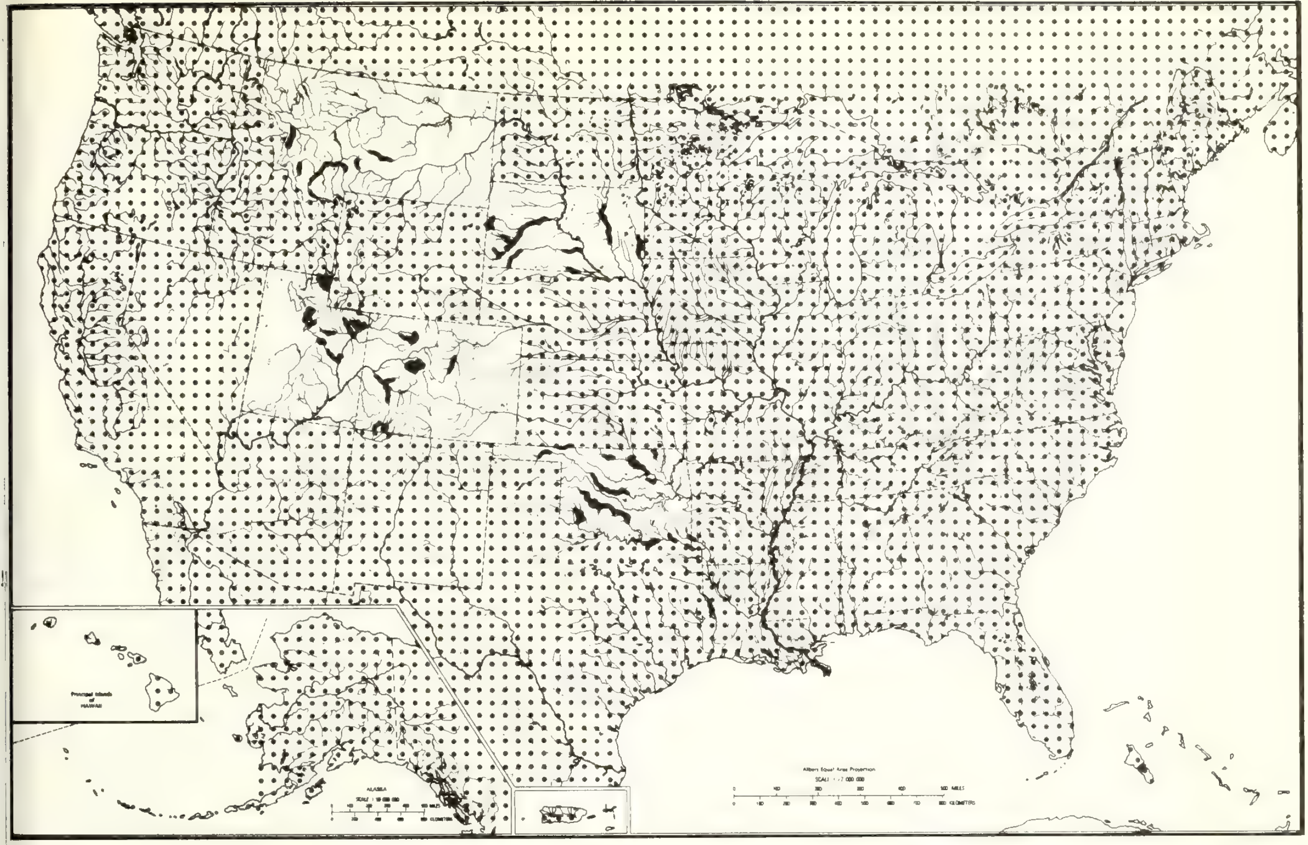


Figure 1.--Partial results of intensive survey of stream reachs with inadequate instream flow conditions due to excessive irrigation divertions.

required by any attempt to improve irrigation efficiencies. Therefore, I'd like to devote the remainder of my time to discussing the proposed "Water Conservation Program" and the opportunity it offers.

First, I would like to read to you just five of the 16 recommendations proposed by the Inter-agency Task Force on Irrigation Efficiencies in their report:

> "Major public investments to improve existing irrigation systems be made after a comprehensive, interdisciplinary analysis has shown that better utilization of the water is needed, feasible, and consistent with state water plans and water rights procedures. This analysis should include assessment of off-site benefits such as maintenance or enhancement of stream flows, water quality, and ground water."
>
> "The governor of each state in which irrigated agriculture is a major water user initiate and maintain a cooperative program through Federal, State, and local agencies and the private sector to bring about improvement in irrigation water use and management and to achieve water conservation (Cooperative Water Conservation Program - see Chapter 7). Legislation should be introduced to provide for Federal grants to the States as needed specifically for this purpose."
>
> "Water quantity and quality data collection programs, including monitering programs, be better coordinated among all agencies. The Federal Government aid the State as appropriate in developing comprehensive and easily accessible records of water use, emphasizing water quantity and quality, irrigation efficiencies, and instream flow needs to facilitate the enforcement of statutes relating to efficient use of water and the forfeiture and abandonment of water rights."
>
> "When conservation measures result in a reduction of incidental water use to maintain vegetative wildlife habitat, a portion of the salvaged water be designated, within State laws, for development of managed fish and wildife habitat."

> "Projects authorized to provide Federal funds to support the development or rehabilitation of irrigation facilities contain arrangements for States and irrigation entities to make appropriate physical, administrative, or legislative provisions to insure protection of water quality and instream flow values, and provide through public involvement a process to determine which stream reaches and instream values should be protected."

These statements give some indication of the recognition of water quality, instream flows, and wetland values contained in the report.

The report concludes that there are up to 38 million acre-feet of excessive diversions which might be left undiverted by rehabilitating diversion structures, canal systems, improved management, etc. While in many western streams this excess water has been filed upon by downstream appropriators as return flows, there are opportunities to provide improved instream flows between the point of diversion and the point of return flow without damaging the water supply of downstream appropriators. There may be trade-offs to be made with the fish and wildlife sector if the excessive diversions are responsible for valuable wetlands in the irrigation service area. There may also be need for construction of additional storage to enable desired management of the water in question. At any rate, it is obvious that detailed, site specific evaluation is needed to make the proper decision.

> "The trend in water planning appears to be toward greater multiple-purpose use of reservoir storage, toward greater State leadership in water use planning and enforcement, and toward increasing protection for all environmental values."

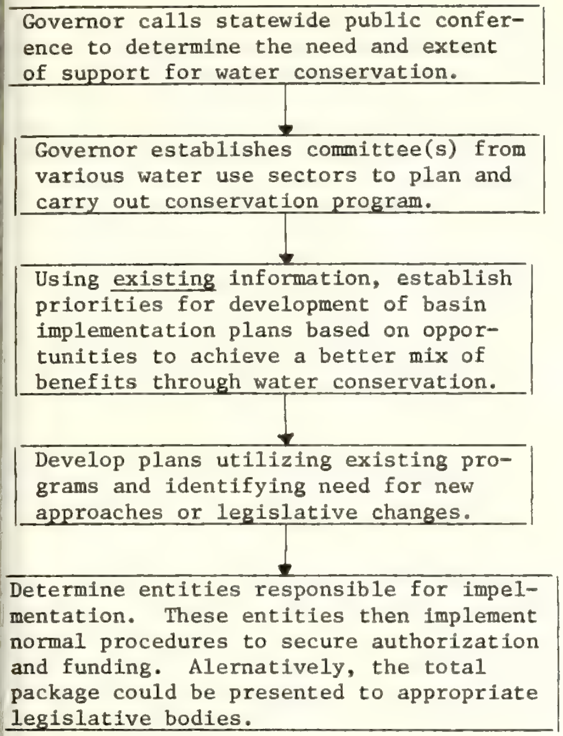
> "In order to achieve better coordination among Federal programs and among the Federal, State, and local levels of government, a positive and concerted effort is needed. To be successful there must be a commitment at all levels of government as well as throughout society that water conservation is an integral part of a successful long-range national water and related land resource program. Such a program must recognize previously mentioned trends and be sharply focused on equitable and attainable objectives."

"To achieve such a coordinated program, State governments should take the lead in the development and coordination of water conservation programs in the State for all water use sectors. Activities of this type are currently under way in some States. All Federal, State, and local organizations should be a part of this coordinated effort. Such a program might be termed a *Cooperative Water Conservation Program*. Federal grants, as necessary, should be made available to the States to bring about the coordinated water conservation programs at the earliest possible time." President Carter in his Water Policy Message mentioned $25 million per year for water conservation program. "Priority should be given to those States Where water use has a major impact on the surface and ground-water supply, water quality, instream flows, and economic stability."

"Saving water for conservation's sake alone is a questionable goal. Before Federal investment in any water conservation program is implemented, the objectives to be served should be clearly defined. Some objectives identified by this study which merit consideration include:

1. Improving farm income through higher crop yields and reduced production costs.
2. Firming up water supplies for junior appropriators.
3. Improving instream flow conditions.
4. Attaining point and nonpoint source pollution control goals.
5. Improving estuary conditions.

The major steps in implementing a Cooperative Water Conservation Program in a State are sketched as follows:"



Governor calls statewide public conference to determine the need and extent of support for water conservation.

Governor establishes committee(s) from various water use sectors to plan and carry out conservation program.

Using existing information, establish priorities for development of basin implementation plans based on opportunities to achieve a better mix of benefits through water conservation.

Develop plans utilizing existing programs and identifying need for new approaches or legislative changes.

Determine entities responsible for impelmentation. These entities then implement normal procedures to secure authorization and funding. Alernatively, the total package could be presented to appropriate legislative bodies.

"The statewide conference is needed to set forth the apparent short- and long-range problems as viewed by responsible people and to determine interest in pursuing solutions. Support for action programs must be evident not only by those who stand to benefit, but also by those who will be responsible for carrying out improvement measures."

"To carry forth with the Cooperative Water Conservation Program following the conference, the governor could establish a committee on irrigation water use and management to plan and carry out that portion of the water conservation program. This committee would consist of representatives of appropriate State and Federal agencies, irrigation and conservation districts, farmers, industry, and public interest groups. Assistance available from existing Federal and State programs could be identified and matched with priority activities. Need for new initiatives or programs could be identified in this manner also."

"Because of the site-specific nature of water and other resource problems, the statewide water conservation program would need to provide for an evaluation of each of the State's hydrologic subunits separately. This is essential to determine the existing water supply and use, the need for additional water, instream flow conditions, water quality, ground water conditions, and water management problems in project areas and on farms. Some of this information is currently available in many states and can be supplemented to set priorities for new measures and programs. Those programs and entities having the most to offer in each basin would be identified in the implementation plan."

IMPLICATION TO FISH AND WILDLIFE AGENCIES

If the proposed water conservation program is authorized and funded, it will offer a new arena for mitigation effort. Effective participation in all activities generated by the program by Fish and Wildlife agencies will be required to capitalize on this opportunity.

Fish and Wildlife agency personnel should:

1. Obtain and read the just released three-agency report.
2. Inventory the river basins to establish the relationship of irrigation water use to wetland and instream flow maintenance and identify those stream reaches where improved irrigation efficiency can produce significant benefits for fish and wildlife.
3. Establish the instream flow requirements of the stream reaches in the priority basins and determine the relationship to irrigation water use and wetlands.
4. Present your choices with information on benefits to be gained at the Governors' conference.
5. Prepare to serve on the committee on irrigation water use and management in your state by budgeting experienced manpower to this effort.
6. Strengthen relationships with agriculture sector entities to enhance later negotiations.
7. Organize your constituents.

With a little preparation and pursuasive presentation of your case, you could attain a degree of mitigation previously believed to be unattainable.

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Development of Mitigation Alternatives: A Process[1]

Adrian H. Farmer[2]

Abstract.--Mitigation involves management of existing habitat to offset habitat commitments to development projects. Even with complete mitigation, there will be a net loss of wildlife management opportunities. Given the limitations of mitigation as a wildlife planning tool, the optimal mitigation pathway is the development of mitigation alternatives directed to wildlife resource objectives and priorities.

INTRODUCTION

The purpose of this paper is to describe e perspective on the process of "mitigation"; ecifically, the development of mitigation ternatives to meet wildlife planning jectives. The concepts discussed have not en developed independently by this author d, in fact, these ideas have been born out the frustrations of many wildlife planners volved in mitigation issues. But, to my owledge, these concepts are not currently braced by guidelines of either Federal or ate wildlife planning agencies.

It is important for me to point out at e beginning that these views on the mitiga- on process have been developed through my tigation experiences, largely with Water source projects, and from my background as terrestrial biologist. I do believe, wever, that these ideas have applicability other types of development projects and osystems.

DEFINITION OF TERMINOLOGY

For purposes of this paper, some wildlife anning terminology related to development ojects must be defined. I realize that e following definitions may not be univer- lly accepted:

(1) Loss prevention. The avoidance of wildlife resource commitments through planning. Very simply, loss prevention requires the development and refinement of land use alternatives that minimize wildlife impacts. Loss prevention results in the preservation of wildlife resource options for the future.

(2) Mitigation. The development and implementation of specific measures to offset unavoidable losses associated with a particular land use alternative.

(3) Enhancement. A net increase in overall wildlife resources above that expected without the proposed land use plan.

The distinction between loss prevention and mitigation as defined above is the term unavoidable. The fact that wildlife losses are avoidable implies there are design alternatives which, although not including specific wildlife measures, would minimize losses. If this distinction is not made one could claim that any development project includes mitigation, no matter what the magnitude of wildlife losses or the consideration given wildlife resources during planning, as long as there is a conceivably more damaging alternative from a wildlife perspective. Loss prevention through good planning is not necessarily equal to mitigation.

Although this may seem to be a subtle and insignificant argument, there are pragmatic reasons to make such a distinction. The three wildlife planning goals discussed above are displayed graphically as bars in Figure 1, the height of which is proportional to the ease of implementation. The arrows represent factors that complicate (suppress) the implementability of wildlife planning objectives. These "suppressing factors" in the Federal water resource programs include planning regulations (i.e., measures labeled as mitigatory may be subjected to different planning requirements), economics (e.g., Federal cost sharing requirements), land requirements, and special congressional authorizations. It should be quite clear that the probablity of including wildlife objectives in a land development plan depends somewhat on the "label" given to them.

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[1] Paper presented at The Mitigation mposium, Colorado State University, Fort llins, Colorado, July 16-20, 1979.

[2] Terrestrial Ecologist, U.S. Fish and ldlife Service, Fort Collins, Colorado.

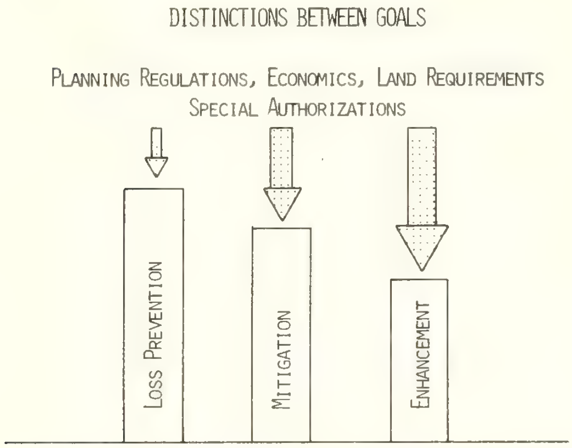

Figure 1. Wildlife planning goals and their relative ease of implementation.

LIMITATIONS OF THE MITIGATION CONCEPT

The planning regulations of Federal water resource agencies usually require that a separate benefit/cost (B/C) ratio be computed for proposed mitigation measures as a means of determining feasibility. The benefits can usually be both monetary and nonmonetary. There are, however, no "benefits" associated with mitigation. The purpose of mitigation is to restore "benefits" unavoidably lost.

Mitigation, with few exceptions, does not increase the number of available wildlife management options. Instead it usually entails management of existing wildlife habitat (options) to increase the supply of wildlife. Therefore, mitigation, in many cases, is a short term substitution for relatively long term and irretrievable losses of wildlife management opportunities. Stated more simply, development projects often make long term withdrawals from the "pool" of potentially productive and manageable wildlife habitat. Mitigation involves the management of habitats left in the "pool". The "pool" will, in the long run, continue to decline.

There also are differing degrees of certainty associated with project losses and related mitigation measures that operate against maintaining wildlife supplies with a shrinking habitat base. The certainties of project related wildlife losses are generally greater than the certainties of maintaining a mitigation/management program because of the complications of continued funding, manpower availability, and unforeseen future land use requirements. One need only look at many Federal reservoir projects which lack the required wildlife management plans, or at the Gathwright Reservoir Project in Virginia which will inundate State owned wildlife management lands, to confirm this.

The limitations of mitigation as a wildlife planning tool can be synopsized as follow

1st Axiom of Mitigation. At best, there will be no net gain in wildlife management options.

> Corollary 1. There will be a genera trend toward net losses of wildlife management options.
>
> Corollary 2. Mitigation is a reactive planning goal incapable of maintaining the status quo.
>
> Corollary 3. The certainties of maintaining a working mitigation measure are less than the certaintie associated with the losses leading t mitigation.

The preceding synopsis of mitigation may be overly restrictive and critical in some views. However, it is important to recognize shortcomings in the frequently believed Pollyannish philosophy that mitigation is the solution to wildlife impact problems and that given mitigation the world will be an equal or better place for humans and wildlife.

I have been somewhat terse in order to highlight the objectives of this paper through the following postulate:

> Given the limitations, the mitigatio concept can be used in a positive mode to more closely comply with wildlife planning objectives.

DEVELOPMENT OF MITIGATION ALTERNATIVE THROUGH PLANNING

The components of a comprehensive wildlif planning process leading to mitigation include at least the following:

(1) Establishment of wildlife objectives and priorities;

(2) Quantification of unavoidable wildlife losses;

(3) Development of a range of mitigation alternatives directed toward meeting wildlife objectives; and

(4) Inclusion of mitigation requirements in project implementation decisions.

The establishment of wildlife planning jectives provides a key to the formulation d evaluation of project alternatives and to e development of a range of mitigation lternatives for consideration. Wildlife jectives can be based on species or communiies but must be developed for a large region, ch as a State or river basin. Wildlife jectives or management priorities may be vailable through previous efforts including ate resource agency programs or by legislaion. If wildlife objectives are not already stablished, they can be set on an ad-hoc basis n an open planning environment with both gency and citizen input.

Figure 2 is an example of a rank-sum rocess for setting priorities for three wildife species. Each species is ranked on a 1-10 ale for each of three criteria with a score f 10 representing the least abundance, greatst vulnerability, and least replaceability. e ranks are totaled by species to yield an ndex (Relative Importance Value (RIV)) for ach species. These RIV scores are used to rioritize potential management objectives. In is example, given equal opportunities, wildife management efforts would be directed to lk, deer, and fox squirrels in that order of riority. The prioritization process does not mply that the deer or fox squirrel resource re expendable, but that elk are the most ressing management target on the basis of the ating criteria used.

WILDLIFE OBJECTIVE SETTING (AD-HOC)

Rank Sum Process Based on 1-10 Scale

	Species Habitat (Units)		
IV Criteria	Deer	Elk	Fox Squirrel
) Abundance	6	8	1
) Vulnerability	8	9	1
) Replaceability	5	10	1
Total	19	27	3
RIV	.70	1.00	.11
Rank	2	1	3

gure 2. The rank-sum process used to prioritize wildlife species.

The RIV scores for each species can be used to determine the relative merit of a management effort. For example, management to provide an optimal acre of deer habitat is only 70% (.7/1.00) as important as development of an optimal acre of elk habitat. Stated in loss/mitigation terms, the loss of an optimal acre of deer habitat is only 70% as significant as an equal loss of elk habitat.

Caution is urged when using RIV scores for numerical comparisons since the rules of ratio mathematics do not necessarily apply. However, with some interpretation of the strict mathematical results, the resource planner should be able to develop a reasonably sound set of RIV scores. This ranking process is performed by most resource planners currently, albeit subjectively and in an undocumented fashion, when comparing impacts to different wildlife species or when trying to define the boundary between mitigation and enhancement.

The quantification of wildlife losses will not be dealt with here because it will be discussed in other presentations during this symposium. Figure 3 provides a display of habitat losses for the three species discussed above. These estimates are in terms of Habitat Units (HU) or equivalent acres of optimal habitat for the species. The habitat losses are converted to an equivalent loss of elk habitat based on the computed RIV values. Stated conversely, mitigation management resulting in the development of 176.5 acres of prime elk habitat would fully mitigate the losses of habitat for all three species.

QUANTITATIVE IMPACT ASSESSMENT

Species	Habitat Impact (HU)	Elk Habitat Mitigation Requirements
Deer (.7)	-100	+70
Elk (1.0)	-90	+90
Fox Squirrel (.11)	-150	+16.5

Figure 3. Habitat losses and their relationship to elk habitat mitigation requirements.

This is a somewhat simplified example but it illustrates how this approach leads to many options for mitigation alternatives. Figure 4 depicts the options from a wildlife management perspective, including mitigation through management of the same or higher priority resources.

The advantages of "out-of-kind" mitigation include management efforts directed to higher priority resources and development of a broader

DEVELOPMENT OF MITIGATION ALTERNATIVES

INCLUDE IN ARRAY OF ALTERNATIVES, MITIGATION FOR HIGHER PRIORITY RESOURCE.

IN ADDITION TO IN-KIND MITIGATION:

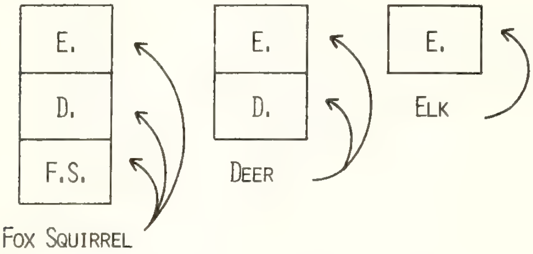

Figure 4. Development of mitigation measures through management of priority wildlife resources.

range of mitigation alternatives. This increases the probability of selecting a mitigation plan readily acceptable to the public and to project decisionmakers.

REQUIREMENTS OF MITIGATION PLANNING

In summary, the mitigation planning concept outlined here requires the following planning components to be successful:

(1) Wildlife planning objectives prioritized and scaled;

(2) Ranking/scaling techniques with more detail and precision than those used here;

(3) Quantitative impact assessment tools and

(4) Planning regulations that treat mitigation objectively.

   a. Planning regulations that delin the bounds between loss preventi mitigation, and enhancement in a clear fashion and which allow management for higher priority resources within the bounds of mitigation.

   b. Mitigation requirements are considered as part of the decisionmaking process and not relegated to an 11th hour consideration after project commitments are made.

Evaluation of Impacts on Fish and Wildlife Habitat and Development of Mitigation Measures[1]

Cathy Short and Mel Schamberger[2]

Abstract.--Mitigation of fish and wildlife losses is predicated on the prediction and quantification of project related impacts as they relate to environmental objectives set for the project. The Habitat Evaluation Procedures (HEP), developed by the U.S. Fish and Wildlife Service, are a standardized methodology that provides environmental data necessary for the impact assessment. The consideration of this data throughout the pre-project evaluation helps establish environmental quality as an integral goal in resource development.

INTRODUCTION

We have assembled to explore the concept o mitigation as it relates to the potential f maintaining and enhancing our fish and w dlife resources. Although the concept of m igation is not new, the desire to implement t s concept has intensified significantly in r ent years. The public no longer supports " velopment at all costs." They are instead i reasingly concerned with "development - at w t cost?"

Mitigation has become both a concept and a rocedure. A better understanding of the p cedural aspect will result if we take the t e to analyze why mitigation efforts are uccessful and what can be done to make m igation a more viable part of resource elopment.

The legal basis for mitigation has been l established by numerous State and Federal l s. Federal agencies must respond to the ire of the people and the intent of Congress apply the concept of mitigation. It is t time that we stop arguing about whether not we will mitigate. We must join together develop scientific procedures that will ter answer the question of "How can we igate?"

The if is political; the how is scientific. I would like to focus our attention on the how of mitigation. Mitigation efforts are often ineffective or nonexistent. There are several basic reasons why mitigation as a procedure fails:

1) Fish and wildlife considerations are not incorporated early in resource development planning;

2) Methodologies to quantitatively predict and evaluate impacts and to assess the effectiveness of mitigation actions have been unavailable in the past;

3) There is little commitment to incorporate or monitor mitigation measures during project implementation. The public is often pitted against resource agencies because of the "our project - your mitigation" attitude of development agencies.

This paper will address the first two aspects of mitigation: 1) Planning and how mitigation enters into the planning process; and 2) a method to develop quantitative data for use in planning and mitigation.

THE PRE-PROJECT EVALUATION

Mitigation of project-related fish and wildlife resource losses is more likely to be implemented when it is an integral component of the planning process than when it is considered as a separate action. Effective mitigation is predicated on the accurate prediction and quantitative evaluation of the impacts of a proposed action on fish and wildlife resources and the incorporation of this knowledge into the planning process.

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[1] Paper presented at The Mitigation posium, Fort Collins, Colorado, July 16-20, 9.

[2] Project Impact Evaluation Group, Office iological Services, U.S. Fish and Wildlife rice, Fort Collins, Colorado.

Planning objectives for each project must be established that meet identified regional problems and needs, including those that involve the protection and enhancement of environmental quality. Project goals in an area with limited wetlands, for example, might include the creation of additional wetland areas that will be attractive to wildlife species and support additional human recreational use.

The most effective consideration of fish and wildlife needs in resource development occurs when they are included at the earliest planning stage. We must accept the challenge to enter into the planning process and to supply the environmental data needed to make mitigation meaningful; we must be willing to push for mitigation planning in projects where none currently exists.

Planning for environmental quality and economic development has historically been the responsibility of the lead planning agency. State and Federal fish and wildlife resource agencies must share the blame with the development agencies for the failure to develop environmental quality objectives. Resource agencies have seldom identified local or regional fish and wildlife priorities even though these needs and opportunities provide the basis for developing environmental objectives. The establishment of environmental objectives for use at the beginning of project planning and the formulation of alternatives that are capable of meeting these objectives is essential if significant losses of fish and wildlife resources are to be minimized or avoided.

Projects can be evaluated in terms of how well they meet planning objectives established for wildlife only if regional and local environmental concerns are identified early in the planning process. Mitigation requests, in the absence of established objectives, will continue to be developed on a piecemeal, ad hoc basis that offers little real protection for the overall integrity of regional environmental quality and ecosystem function.

It is gratifying to see that some states have begun to enter successfully into the process of establishing priorities for their fish and wildlife resources. The presence of ,these guidelines facilitate the assessment of impacts and provide a sound basis for project approval, modification, or opposition.

Controversies over mitigative measures will be greatly reduced if we integrate wildlife considerations and objectives throughout the planning process. Concurrent consideratio of economic and environmental concerns can sto the needless loss of environmental quality as other resources are developed. Mitigation wil never be an effective tool to protect our fish and wildlife resources as long as it remains a "add-on" package to projects, left to the funding whims of Congress.

We must recognize the fact that we cannot grow as a Nation without some resource sacrifi We can, however, propose projects that are truely in the best public interest by identifying regional fish and wildlife priorities, setting environmental project objectives, and including mitigation as an integral portion of project planning.

QUANTITATIVE ASSESSMENT OF IMPACTS AND MITIGATION MEASURES

The second major topic of this paper centers around methodologies that provide the types of environmental data that are needed in the planning and mitigation process. The lack of standardized methodologies capable of quantifying environmental values has been at least partly responsible for the lethargic consideration of fish and wildlife values in project planning. The level of mitigation needed and the effectiveness of mitigation measures could not be adequately determined without the quantification of losses. This excuse is not longer valid - methodologies hav been developed that are capable of quantitatively evaluating impacts on fish and wildlife habitat.

The questions of "Why a new approach?" an "Why a habitat approach?" have been raised. These questions are most effectively answered by looking at the three methods of assessing project impacts that traditionally have been available to decisionmakers:

1) Subjective evaluation (sometimes referred to as the "good old boy" approach). Personal opinion of impacts on fish and wildlife habitat and necessary mitigation actions hav been effective in very few cases. Problems that arise with basing mitigation on subjective evaluations include: 1) There is little or no ability to replicate results between individuals or projects; 2) inconsistent consideration of fish and wildlife resources may occur; 3) losses that are difficult to evaluat

subjectively are often ignored; 4) disagreements between different biologists working on a project may lead to even greater environmental losses; and 5) subjective assessments have little creditability in legal sitations. A recent study of four methods of habitat evaluation clearly showed that biological information, to be useful, must be replicable and documented with written criteria (Ellis et al., 1978). The high variance associated with subjective habitat evaluation makes it inappropriate for the assessment of project impacts.

2) Population data. Population data are only a snapshot in time and space. They are useful for describing baseline or existing conditions but lack the capability of predicting population trends or the ability to evaluate the number of animals the habitat is able to sustain. One example of the limitations of population data in mitigation planning is the results of recent field tests in Wyoming by the U.S. Fish and Wildlife Service (unpublished data). Habitat suitability for selected wildlife species was evaluated for these sites by: 1) Pattern recognition models; 2) written criteria established for use with the USFWS Habitat Evaluation Procedures; 3) subjective evaluations; and 4) population data. The first three methods yielded similarly high estimates of the numbers of animals the habitat could be expected to support although population data consistently indicated low animal numbers. A check of historical information from the area showed that poaching was a significant mortality factor controlling animal numbers. Mitigation based on population data alone would not reflect the true loss of wildlife habitat.

3) Man-days of use. The major shortcoming of the man-days of use approach to impact assessment is that it is based on use rather than productivity. Fish and wildlife concerns are considered mitigated if an area supports the same number of use days after completion of a project as it did before. Areas of high productivity but little use receive low values and any increase in use is perceived as a project benefit, even if a decrease in the resource base occurs. This is appropriate when considering the economic ledger but is not applicable to the ecological or environmental ledger because unused wildlife supply, although available, is not considered.

The consideration of these traditional methods makes it obvious that quantitative assessment of impacts is fundamental to successful environmental planning and mitigation. The need for a standardized evaluation tool, accepted by all the involved agencies, has become critical. The USFWS has been working over the past several years to develop a quantitative assessment methodology that will fill the need for procedures that are scientifically sound, objective, of acceptable validity, and capable of generating biological impact data that are replicable and documented. These procedures, the Habitat Evaluation Procedures (HEP), represent state-of-the-art knowledge and will continue to be revised to reflect the best current technology.

The HEP, developed from a system formulated by Daniel and Lemaire (1974), are based on the concept that all land has existing wildlife values that can be expressed numerically. These procedures also can be used for an economic impact assessment where fish and wildlife values are measured in terms of changes in dollar values and/or man's use of the resource.

One of the most important aspects of the HEP methodology is its capability to quantify the noneconomic value of fish and wildlife resources by measuring impacts and formulating mitigation measures on a biological basis rather than solely on a "use" basis. The concept that impacts on fish and wildlife resources and mitigation actions should be evaluated in ecological terms rather than monetary terms is most significant. This is not to imply that dollar values have no place in impact assessment. They can and should be used to evaluate project contributions to economic objectives. Economic values should not, however, continue to be used to assess environmental impacts or as a basis for mitigation.

The nonmonetary portion of HEP is a standardized accounting system that quantitatively displays baseline and various future conditions. This system assumes that: 1) Habitat value can be quantified; 2) habitat suitability for a particular fish or wildlife species can be determined by measuring physical and chemical parameters of the habitat; 3) habitat can be evaluated by assessing the suitability of that habitat for selected species; and 4) habitat quality and quantity are directly related to potential animal numbers.

The habitat value, representative of the ability of the habitat to support fish and wildlife species, is represented by a single index number that integrates quantitative measures of habitat quality and quantity:

Habitat Quality x Habitat Quantity =
Habitat Index

Habitat Suitability Index (HSI) x Area =
Habitat Units (HU's)

The basic HEP methodology uses this simple relationship to provide ecological data for the comparison of impacts over time of alternative project plans to species, species groups or life stages, cover types, or areas of homogeneous project impact. The Habitat Suitability Index (HSI) is a critical set of data that are entered into the HEP. The HSI can be determined for either species or cover types although the major emphasis in most impact assessments is on species. The use of the HEP aids in environmental planning and in the selection of alternative plans that most nearly meet the established project objectives.

The USFWS has the legal responsibility, along with the States, to recommend project modifications and measures to mitigate adverse impacts. These mitigation recommendations, to be effective, should be well documented and based on quantitative evaluations of project related impacts on fish and wildlife habitat. Decisions concerning the mitigation of fish and wildlife losses usually are made on the basis of several sets of data: 1) Biological data on current resources, probable impacts, and related implications; 2) economic considerations; 3) societal preferences; and 4) political realities. Data on biological and economic values can be provided by the HEP; information on societal preferences is difficult to obtain or quantify. The form that mitigation takes will, in the end, be determined by monetary and political constraints.

Mitigation, when needed, should be based on replacing the resource base and not the use of that resource. It is important to realize that productivity lost is not mitigated by fish and wildlife already present on areas prior to their purchase. Mitigation must call for increased productivity through some form of active or passive management. The Habitat Evaluation Procedures can be used to provide data on anticipated changes in habitat productivity associated with various project features, as well as to analyze the degree to which mitigative measures can be expected to alleviate or replace resource losses.

Several improvements have occurred in t HEP methodology since it was published in 19 These include:

1) The ability to evaluate impacts by species or life stages as well as by cover type;
2) Improved guidance in species and cover type selection, sampling design, and other critical areas;
3) Clarification of concepts;
4) Emphasis on HEP as an evaluation t that can be used throughout the planning process;
5) Expanded descriptions of the vario applications of HEP in resource management;
6) Refinements of the monetary approa to conform to revised Principles a Standards guidance; and
7) Separation of policy from scientifi procedures.

Numerical examples illustrating the appl cation of HEP in impact assessment as well a more detailed discussions of concepts have b presented in several other papers (Schamberge and Farmer 1978; Schamberger 1979; Schamberge et al. in press; Short and Schamberger in press) and are beyond the scope of this presentation. The Procedures, first published i 1976 (U.S. Fish and Wildlife Service 1976) a being updated and refined by the Project Impa Evaluation Group in Fort Collins, Colorado. Publication of the revised Habitat Evaluatio Procedures is anticipated in late 1979.

SUMMARY

The real issue in mitigation is whether not agencies will incorporate legitimate environmental objectives into the planning process and adequately and accurately display project related impacts to fish and wildlife resources. Public concern, political mandate and the development of standardized quantitative evaluation tools have made mitigation concerns an integral part of resource develop

The key to effective mitigation is the inclusion of environmental objectives early i project planning and the formulation and sele tion of project plans that can meet these objectives. The use of a standardized methodology to predict and quantify impacts to fis and wildlife resources is critical if environmental quality is to be a meaningful goal.

Data from a HEP analysis can be used to valuate the impacts of alternative project lans on fish and wildlife resources, formulate itigation measures, and determine the degree o which mitigation/ compensation efforts are uccessful. These Procedures, used to provide ata throughout the planning process, are an ffective means to access project-related mpacts and provide the necessary environmental ata for sound mitigation decisions.

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Evaluation of Terrestrial Habitat Evaluation Procedures and Their Use in a Critical Habitat Situation [1]

J. B. Mathies[2] and B. E. Barrett[3]

Abstract--260,623 hectares (644,000 acres) of land surrounding the Dickey-Lincoln School Lakes Project in northern Maine were evaluated by a modified form of the 1976 version of the habitat evaluation procedures. Two mitigation reports were prepared, differing about two-fold in acreage recommended for mitigation. Resolution of problems encountered are discussed. Winter deer yards are critical for deer survival in northern Maine and we present the procedures used to evaluate mitigation for this game animal.

INTRODUCTION

The Dickey-Lincoln School Lakes Project is a proposed multipurpose hydroelectric installation on the St. John River located in extreme northern Maine parallel to the Canadian border. Dickey Lake and Dam would require 34,813 ha (86,024 ac) of land and would be used to provide additional peaking power capabilities for all New England states (COE 1978). Lincoln School Lake and Dam would require 1,060 ha (2,619 ac) of land located downstream from Dickey Dam. Its purpose would be streamflow regulation, power generation and maintenance of a source of water for pump-back to Dickey Lake. The purpose of this paper is to present the history of the mitigation process as it is evolving for this project, to present some recommendations for refining the habitat evaluation procedures (HEP) and to discuss use of the procedures in a critical habitat situation.

ENVIRONMENTAL SETTING

The Dickey-Lincoln Project area is primarily industrial forest land which is currently a mature second-growth forest with an active on-going timber harvesting program. The land area is situated in a transitional zone between the Boreal Forest Formation and the Eastern Deciduous Forest Formation (Oosting 1958). As such, the forests are primarily spruce-fir in the lowlands and northern hardwoods on the ridges. Mixed stands occur between the purely coniferous and deciduous forests. Areas which have been burned or where bare soil has been exposed usually result in poplar-birch stands of various acreages. Interspersed throughout are rivers, streams, lakes, marshes and bogs. Access to the majority of the project area is controlled by the North Maine Woods Association and the minimal development and remoteness lends a distinctive near-wilderness appearance to the area.

EVALUATION PROCEDURES

All federal water-related projects now require evaluation of wildlife losses and mitigation of losses within a framework which requires the Corps of Engineers, as the lead agency, to maximize overall project benefits (P.L. 85-624). A team of wildlife biologists was formed by the Corps to assist in meeting these requirements and was composed of two Maine Department of Inland Fisheries and Wildlife (MDIFW) personnel, a representative of the U.S. Fish and Wildlife Service (FWS) and a representative from ERT, the terrestrial ecology consultant for the Corps.

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[1] Paper presented at The Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

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Early in the project, various authorities had expressed concern about wildlife impacts which could extend beyond the influence of the impoundments themselves. Thus an area within a two-mile radius of the lakes was evaluated encompassing a total of 644,000 acres of land. Color infrared (CIR) aerial photographs (scale = 1:20,000) and vegetative type boundaries were available for this entire area. For evaluation purposes, the 133 different vegetative types identified on the CIR photos were condensed into nine habitat types for application of a modified version of the then-existing habitat evaluation procedures (USFWS 1976). The team evaluated a total of 80 sites during August 1977 utilizing USFWS Form 3-1101 of the procedures. The process involved the subjective evaluation of each site for 10 animal species by each team member individually, and then a verbal comparison of each species ranking while on the site. A total of 31 wildlife species were evaluated within the nine habitat types (ERT 1977). Species selected by the team were representative and common species expected to occur in this northern Maine area. Only the moose was evaluated in every habitat type, and some species were evaluated in only a single habitat type.

RESULTS AND DISCUSSION

Two separate mitigation reports were prepared from data collected by the team. The FWS prepared a Conservation and Development (C&D) Report in January 1978 which has been updated by two supplements (USFWS 1978). Their current mitigation recommendation involves 64,751 ha (160,000 ac) of land with 22,177 ha (54,800 ac) of deer wintering habitat included within the total area. The terrestrial ecology consultant to the Corps also prepared a mitigation report in July 1978 (ERT 1978). This report recommends purchase of 36,357 ha (89,838 ac) of land of which 6,238 ha (15,413 ac) should be deer wintering habitat. Currently, work is near completion on a third mitigation report which the Corps of Engineers is preparing based upon desirable elements of both previous reports. This final report will be presented with the Final Environmental Impact Statement (FEIS) which will be presented to the U.S. Congress for approval of both the project and the proposed mitigation plan.

The consultant's and FWS' mitigation plans differ in philosophy, approach, and creages required for mitigation. The emainder of this paper presents these iffering views concerning mitigation for he Dickey-Lincoln School Lakes Project and roblems encountered in analysis.

Interspersion Versus Intraspersion

The evaluation team decided to consider only the pure habitat types and did not evaluate interspersion of habitat types while in the field. Interspersion was later evaluated mechanically utilizing aerial photographs with habitat type boundary delineations to determine the number of different habitat types within a 65-ha (160-ac) area centered on each plot. Later consideration by the team resulted in deletion of interspersion from the FWS analysis. Deletion was due to a general inability of the team to visualize interspersion at year 100 of the project life as well as a feeling that intraspersion could be equated to interspersion in a selectively-cut forest. In this case, intraspersion includes group selection and patch clearcuts which would be too small to identify as separate vegetative types, but would vary in both age and species composition from the overall type classification.

The consultant's report took the view that both interspersion of habitat types and intraspersion within each habitat type had value for wildlife. Additional justification for including interspersion resulted from a consideration of species such as the white-tailed deer which require more than a single habitat type in order to meet their annual life requisites. Without including interspersion, the habitat unit value (HUV) for deer within a single habitat type could never attain the maximum value of 10. Inclusion of interspersion in the mitigation analysis was thus deemed essential for a correct interpretation of the existing value of project lands for wildlife species.

White-tailed Deer

Perhaps the most important wildlife species in the project area is the white-tailed deer. The most critical habitat requirement of deer in northern Maine is winter range.[4] Extreme snow depths concentrate deer during the winter period; these wintering habitats are characteristically dense, mature, spruce-fir forests adjacent to rivers, streams, or lakes. Winter habitats generally comprise about 10% of the total land area and deer may move several miles or more from summer range to winter range. Carrying capacity of the wintering habitat is a determinant of deer populations in surrounding lands. Impact of the Dickey-Lincoln Project on deer has been estimated at close to a 50% reduction in deer populations within a 27-township area.

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[4] We do not mean to imply the legal connotation of "critical habitat" per Section 7 of the Endangered Species Act.

Although deer were evaluated in seven of the nine habitat types as a normal evaluation element, the importance of deer as a big-game species and the projected loss of 50% of their wintering habitat resulted in special analyses and reports being prepared to estimate impact and mitigation for deer. It was felt by State of Maine biologists that too little was known about deer in the project area and the FWS (1976) procedures were not known well enough to consider their use to evaluate the critical habitat for deer. A long-term study has been undertaken by the MDIFW to locate all deer winter habitat within a 27-township area and to estimate the size of the deer herd dependent upon this winter habitat. Aerial flights were flown each year during winter and all deer trail concentrations were delineated on topographic maps. Population estimates were made from hunter harvest data and from prior estimates made within the deer management plan for Maine.

The proposed deer mitigation by the FWS has changed from 59% mitigation of deer losses in initial reports to 100% mitigation in the latest supplement based upon additional data collected since the first report. A total of 22,177 ha (54,800 ac) of deer winter habitat would require management to double the carrying capacity from currently existing levels.

The Corps' consultant proposed replacement of a deer herd sufficient to maintain the harvestable crop of deer estimated to be required by projected hunter demand over the life of the project. A total of 6,930 ha (17,125 ac) would be required to mitigate hunter demand and a similar doubling of carrying capacity in deer winter habitat would be required. As the project area is currently underharvested for deer, mitigation of hunter demand was deemed adequate mitigation for this species.

Two research projects were proposed by the Corps' consultant to determine if complete mitigation would be possible in addition to deer winter habitat management. Deer supposedly utilize traditional winter habitat and if that habitat is destroyed, deer utilizing that habitat may not survive. To test this theory, we propose that all deer winter habitat within a single valley in the impoundment zone be clearcut. Surveys would then be made to determine whether deer remained in the clearcut winter habitat, moved to traditional winter habitat in other valleys, or created new winter habitat from previously unutilized habitats adjacent to the clearcut. A second research project would be to determine whether deer will follow logging activities in northern Maine. Harvesting timber during winter in areas adjacent to deer winter habitat may reduce the dependence of deer on traditional winter habitats in the project area.

There is also a suggestion that deer management may not be ideally suited for northern Maine (Peppard 1979). Deer were not found in the project area until after 1880 when timber harvesting opened up the dense forests and deer could establish and maintain themselves. Recently, climatic conditions appear to be cooling down, and deer populations are declining. The project area may be better suited to moose management than to deer management. In conclusion, the mitigation status of white-tailed deer has not been finalized, although current plans are to manage a large acreage of remaining winter habitat in an attempt to double the carrying capacity.

Edge Species

While conducting the habitat analysis, the team decided that an additional habitat should be evaluated on the project area. This habitat was the road edge and it appeared to be an important habitat for species such as the ruffed grouse. Large forested areas occur in northern Maine where the only edge is adjacent to the few roads which traverse the area. Road edges were later discarded as a part of the analysis due to the lack of data pertaining to this linear habitat type. Procedures for analyzing edge species are currently being revised by the FWS.

Deep Woods Species

Some species evaluated by the team (e.g., spruce grouse, marten and lynx) are typical of mature, dense forests. These species are, in general, detrimentally affected by any management plan other than perhaps wilderness preservation. The intent of mitigation for these species is to manage the deer winter habitat acreage not only for deer but for these other species as well. It is anticipated that large acreages of deer winter habitat will occur in the mitigation lands, and that the minimal level of management dictated within such habitat will be best suited for maintenance of these deep woods species, but within the deer winter habitat only.

An associated problem is how to treat these deer winter habitat lands in the context of total mitigation for all species. Deer winter habitat will have mitigation benefits or other species, but the limited manage-ent allowed in such habitat will not allow he full management potential of other itigation lands to be achieved. Thus a artial mitigation on these lands is possible nd resolution of the process for handling hese lands is continuing. It appears that management potential must be determined or deer winter habitat and a reduction made or the total amount of mature spruce-fir creage required for mitigation. We resently assume a 10% reduction in deer inter habitat due to this added benefit for eep woods species.

Maximum Habitat Unit Value For a Species

FWS assumes that a maximum value of 10 1.0 in the new procedures) can be assigned in ptimum habitat for a species (USFWS 1979). e view this as the maximum value that can be chieved in natural habitats rather than in tensively managed habitats. Included in tural habitat influences are fire, wind-row, and agricultural and forestry actices. We believe that values greater an 10 can be achieved, but at the expense of ded energy inputs into the system. Specific ldlife management techniques such as annual eding, food plot establishment, nest platrms and nest boxes can be installed on tigation lands in order to improve the isting habitat.

This philosophy requires further planation. In order to increase the rrying capacity of a unit of land, managent activities must be effected. Any nagement activity will, in general, change bitat from its existing condition. anged habitat will inevitably effect anges in population levels and species mposition. Thus we cannot consider e-for-one replacement of organisms lost e to project activities. It makes more nse to mitigate for lost biomass than to tempt to achieve one-for-one replacement. other result of management activities is e creation of a degree of unnaturalness in e natural system (e.g., water guzzlers in id regions). The degree of artificiality lowed in wildlife management practices ll be determined by public acceptance. We e not advocating agri-business practices ich attempt to maximize biomass productivity t we do believe that management practices n produce greater biomass than produced in timal natural habitats. As new management chniques are developed and applied, the rrying capacity in optimal habitat is pected to increase. At times, such creases in one species will result in creases in other species, but the goal of creasing biomass over that found in natural systems is deemed possible. This approach will always have a constant value of 1.0 for optimal natural habitat, whereas the FWS (1979) approach would appear to have a constantly changing scale as new management techniques dictate new and higher population levels as the optimum in managed habitat. We also believe that the complex of wildlife species is better known for natural habitats than for managed habitats, thus allowing more accurate predictions for mitigation purposes. Thus we believe that adding energy to natural habitats should allow habitat unit values to exceed the maximum of 1.0 for a species.

CONCLUSIONS

The mitigation planning process is continuing on the Dickey-Lincoln School Lakes Project and final conclusions cannot be derived presently. Current status of mitigation strategies is depicted utilizing an example of existing vegetative types from the project area (fig. 1). The FWS approach involves a fairly low intensity of management on 64,751 ha (160,000 ac) of land and utilizes a selectively-cut forest to attain mitigation (fig. 2). The consultant's approach involves a high intensity of management on 36,357 ha (89,838 ac) of land utilizing selection-cuts, clearcuts and modification of forest stands to increase diversity and interspersion of habitat types (fig. 3). In our opinion, either approach would achieve adequate mitigation for this project.

Our experiences to date have indicated some problem areas with the old, subjective habitat evaluation procedures. Some of these problems have already been resolved within the new HEP guidelines (USFWS 1979), and others are currently being addressed by the FWS. We would recommend that procedures be developed for handling critical habitat situations within the HEP. As these problems are resolved, future evaluations should benefit from problems such as those expressed in this paper which were encountered during early applications of the HEP.

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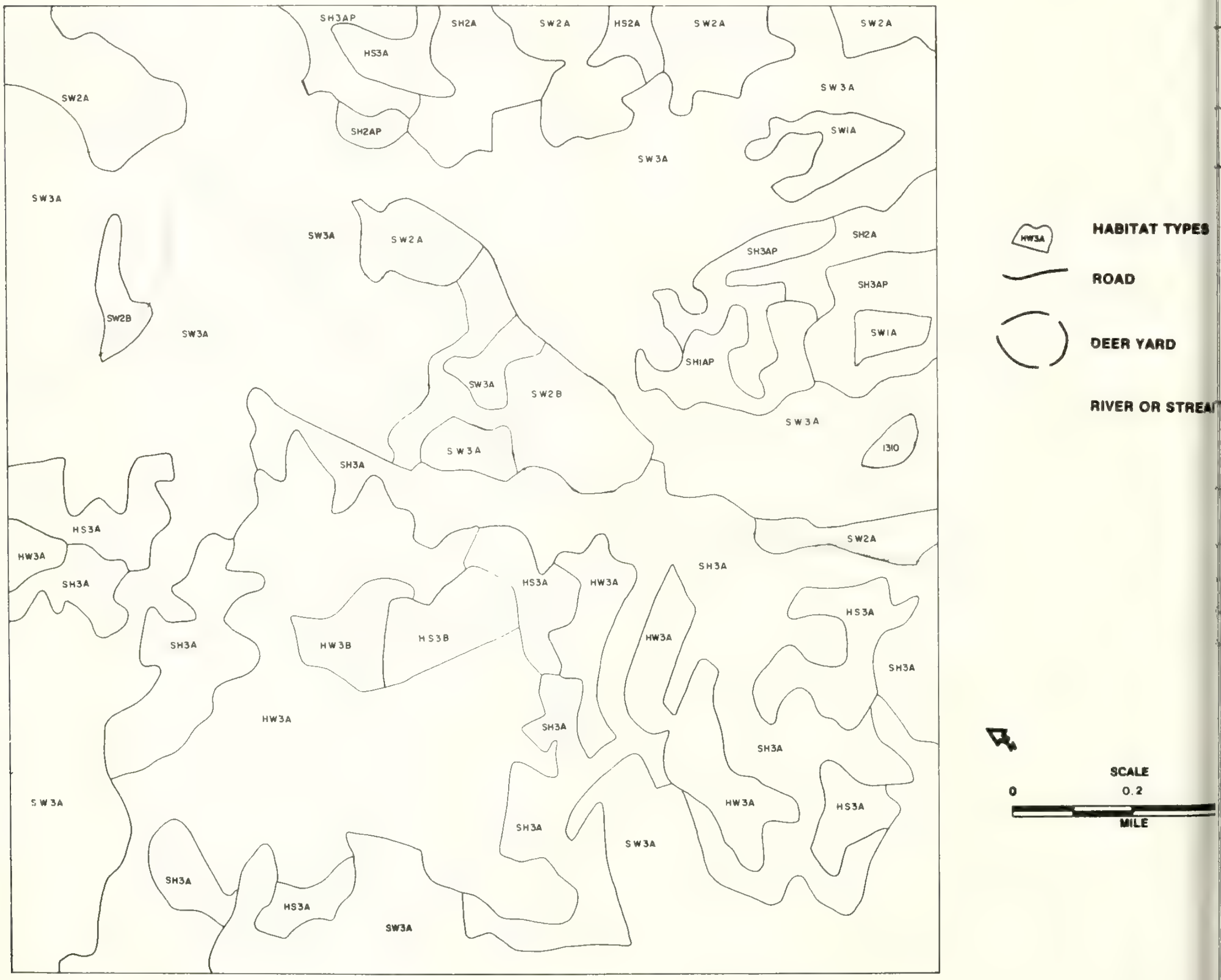

Figure 1. Example of existing vegetative types on the Dickey-Lincoln School Lakes Project, Maine. (See Appendix 1 for description of symbols.)

Appendix 1

Forest and Land Cover Code

Forest Land Classifications

Each habitat type map delineates forest associations according to species composition, height, and density. For example, the type symbol SW3A refers to predominately spruce-fir forest (SW) which is greater than 50 feet in height (3) with a crown closure of 75-100% (A). Suffix letters are used to indicate additional association characteristics as described herein.

Forest type symbols:

SW - Conifers, predominately spruce-fir, 75-100% of type.

HW - Northern hardwoods, sugar maple-beech-yellow birch, 75-100%.

SH - Conifer and northern hardwood mixture with 50-75% conifers.

HS - Northern hardwood and conifer mixture with 50-75% northern hardwoods.

PO - Aspen, including trembling aspen, bigtooth aspen, and balsam poplar covering 75-100%.

PB - Aspen-birch mixture with aspen predominating.

CS - Northern white cedar swamp covering 75% or more of type.

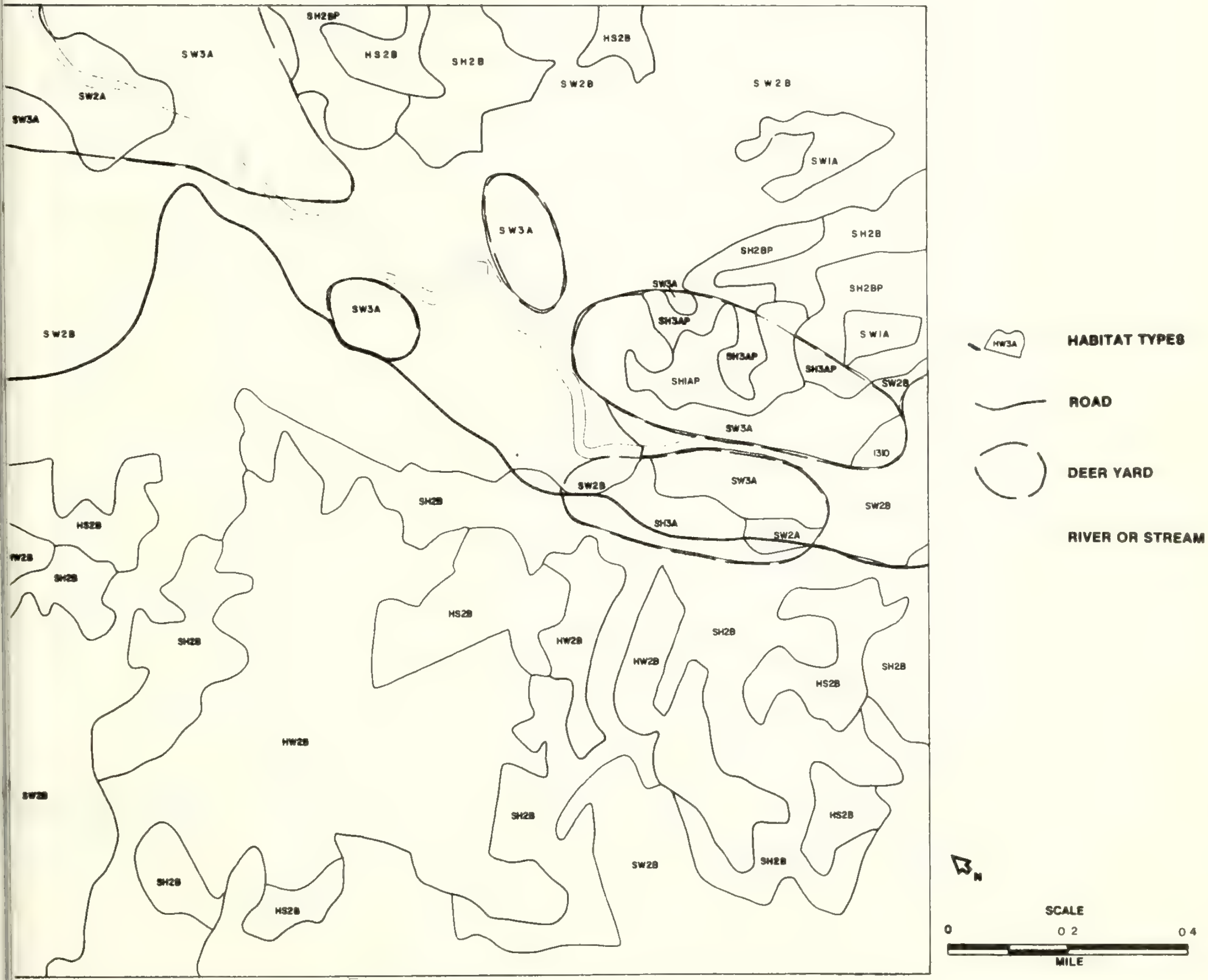

Figure 2. Projected result of low-intensity mitigation plan for the Dickey-Lincoln School Lakes Project, Maine.

Height and density of crown closure:

Height

1 - Up to 30 feet
2 - 31-49 feet
3 - 50 feet and up

Density (percent crown closure)

A - 75-100
B - 31-74
C - 0-30

Type Suffixes:

P, B, N - Suffixes referring to predominant species component in mixed forest types: Aspen, birch and pine, respectively.

O - Suffix indicates planted to oak species.

Nonforest Type Classifications

1310 - Alder - dogwood - willow
4110 - River

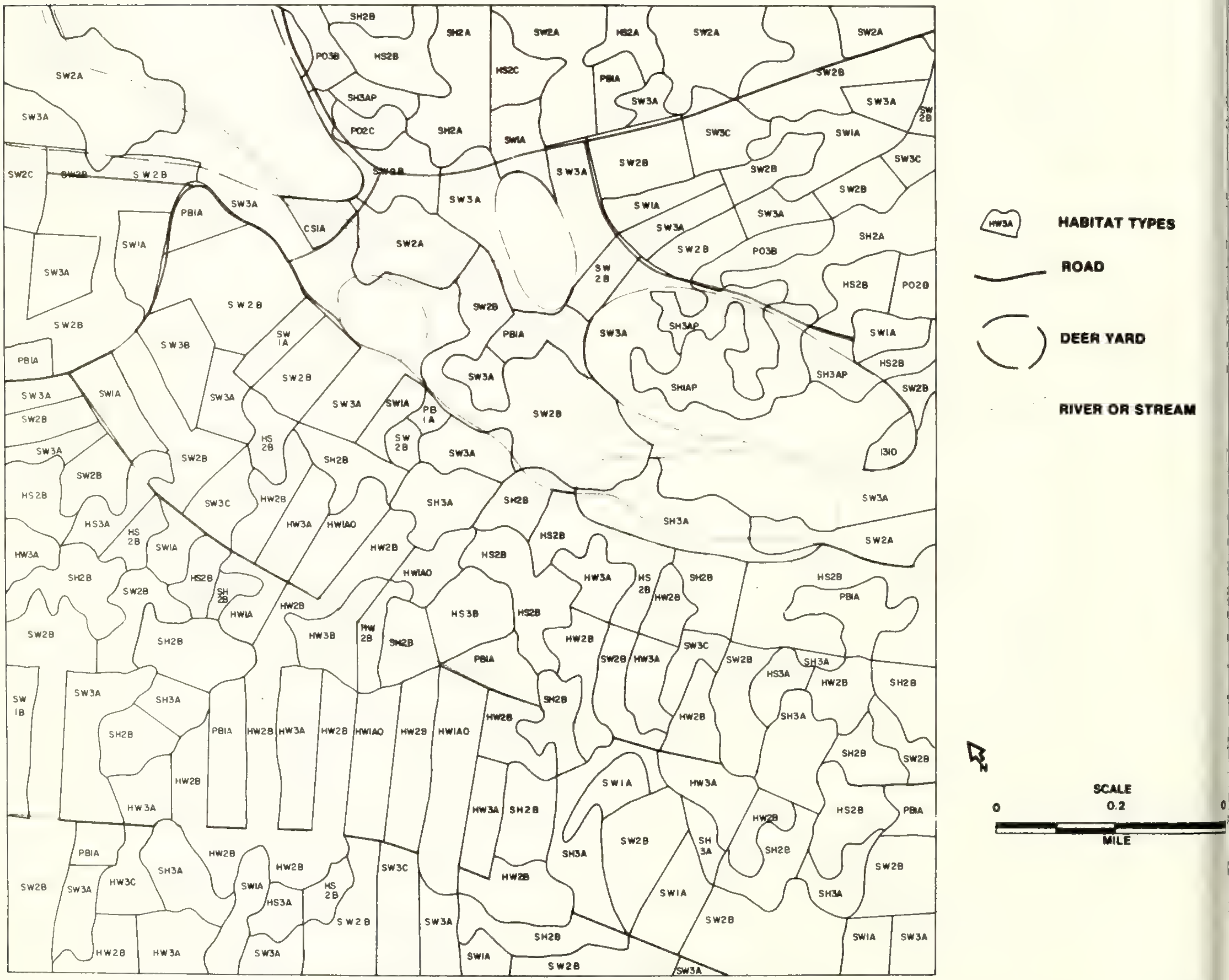

Figure 3. Projected result of high-intensity mitigation plan for the Dickey-Lincoln School Lakes Project, Maine.

Mitigation and the Multiobjective Planning Process[1]

Radford S. Hall[2] and Thomas R. Vogt[3]

Use of the revised Habitat Evaluation Procedures in resource development planning. A report on a Corps of Engineers - U.S. Fish and Wildlife Service cooperative inter-agency effort to integrate and evaluate habitat evaluation as a means to achieve environmental quality objectives within the multiobjective planning process thereby reducing mitigation and/or compensation requirements.

INTRODUCTION

Natural resource development planning has experienced evolutionary change over the years which in retrospect reflected the character and priorities of a young and growing nation. During the early growth period of this country, the number of projects were few, and the framework and level of detail of planning studies were much more simplified, if conducted at all. Natural resources were thought to be limitless and the priorities of the Nation were focused on development. Resources development planning involved one purpose at a time and emphasized one major objective, that being national economic efficiency.

As the nation grew and development progressed, we became aware that our natural resources were not infinite and that the development of one may well result in the loss of another. Societal priorities and preferences began to change, so much so that today public priorities, relative to natural resources must now be multipurpose and multiobjective in approach to meet contemporary demands for social and environmental accountability.

Government as well as private resource development entities are faced with responding in an appropriate fashion to the concerns and values of modern society. At the Federal level this response has been mandated by comprehensive actions such as the Fish and Wildlife Coordination Act of 1934, the National Environmental Policy Act of 1969, and the Principles and Standards for Planning Water and Related Land Resources (WRC 1973).

Resources planning has evolved from what was once basically a need decision, i.e. a plan selected solely on its ability to meet a specific need, to that which incorporated a financial evaluation, (benefit-cost ratio) and finally, to the multiobjective, multipurpose, and multiple impact nature that constitutes today's planning climate. Planning in this sense may now be viewed as analogous to an art, that is: a blending of several disciplines within a general methodological framework, coupled with judgement and experience.

To provide Federal resource planners with the framework for this activity, several agencies have developed specific planning processes or guidelines, examples of which include the Soil Conservation Service's "Project Planning and Documentation Guide" and the Corps of Engineers' "Multiobjective Planning Process." While to some degree each of these processes is unique, they share common goals and basic structures. As required by legislative and administrative actions, all such procedures direct Federal management and/or project planning toward broader purposes and consider a wider range of alternatives and impacts in so doing.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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As opposed to the simplified planning of the past, current planning requires the identification and quantification of impacts of alternative actions associated with resource use and development. In many cases they may be difficult or even impossible to measure and quantify. Many recent resource planning efforts have been characterized by frustration in attempting to deal with public values which are inherently non-quantifiable or quantifiable but in different terms, making them difficult to comparatively evaluate. One such area has been the measurement of environmental impacts and more specifically their quantification in a system which would provide a measurement value of the impact.

The purpose of this paper is to discuss an attempt to develop a quantitative evaluation method for certain previously intangible values and to consider its planning implementation. It should be noted however, that certain values may be inherently non-quantifiable. Where such values exist, it is tempting to ignore or minimize their role due to their intrinsically subjective and controversial nature. It is precisely the consideration of these subjective elements however, which relegate planning to an art and test the subtle skills, judgement and experience of the planning professional in addressing the problems and needs of today's society.

MULTIOBJECTIVE PLANNING

The National Environmental Policy Act (NEPA), the Principles and Standards, and other authorities establish and define national objectives for water resource planning. They also specify the range of impacts that must be assessed, and set forth conditions and criteria which must be applied when evaluating plans. The Principles and Standards require that Federal and Federally assisted water and related land planning be directed to achieve National Economic Development (NED) and Environmental Quality (EQ) as equal national objectives. These national objectives are interpreted as being consistent with and reflective of the concept of total environment set forth in NEPA.

To guide planning for the conservation, development, and management of water and related land resources consistent with the Principles and Standards and other directives, the Corps of Engineers has developed a multiobjective planning process (Army Corps 1978). This process consists basically of four functional planning tasks performed to varying levels of detail within three plan development stages as shown in Figure 1.

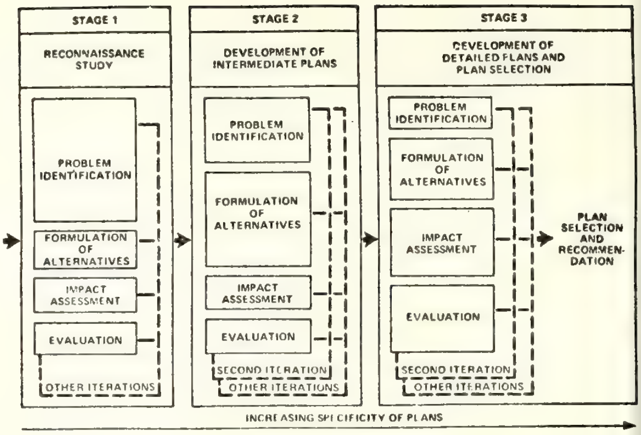

Figure 1. General relationship of plan develop- stages and functional planning tasks (U.S. Army Corps of Engineers).

The multiobjective planning process provies a framework within which a wider range of criteria may be used for assessing actions. Multiobjective planning offers the potential for consideration of numerous system and subsystem interrelationships and the handling of a large and comprehensive variety of alternatives. Effective evaluation of a subsystem requires objective, quantitative and acceptable resource information being available in a timely manner. Comprehensive planning of this nature while desirable, may be expensive both in time and labor and may encounter budget constraints as well as a limitation imposed by the extent of information that can be effectively presented to and utilized by decisionmakers.

In the past, resource planning generally focused on single purposes and, as such, projects were formulated for a single need. If impacts were of such magnitude that compensation was required, this was done apart from the formulation and design of the project. Multiobjective planning, a more anticipatory approach to resource development, allows the identification and consideration of impacts and their interrelationships with other values through the planning process. One purpose of this consideration is the development of a range of alternatives including those which minimize losses and/or incorporate mitigative measures. The Corps of Engineers' multiobjective planning process through development and evaluation of a range of NED and EQ alternatives is designed to accomplish this function and to consider measures recommended to conserve wildlife resources, both with regard to the project and its alternatives.

The objectives of planning imply a need in the present for information about the future. Thus, methodologies to provide predictive information upon the status and potential of selected resources impacted by alternative courses of action are essential for multiobjective planning to be effective. As all elements of a resource may not be valued equally at any given time, any method developed to provide predictive data must also have a capacity to assess a full spectrum of values to specific elements of the resource. This ability is necessary to allow the planning process to respond to the identified problems and needs through tradeoff analysis and true resource values.

For an evaluation method to effectively aid in multiobjective resource development planning, the following basic criteria must be met:

1. The method must be verified as technically sound and objective;

2. The validity must be accepted by the agencies and decision-makers involved;

3. The method must be implementable within the planning framework;

4. The data generated must be documented, replicable and compatable in detail with other elements of the planning process; and,

5. Users must be fully trained and understand the methodology.

FISH AND WILDLIFE EVALUATION

"The biggest hazard in the search for approaches to difficult problems is the expectation that traditional deterministic procedures are available or can be established immediately" (Valachos 1977). One such problem which arose with the evolving concern over resource development was the impact upon fish and wildlife resources. As the perception that such resources were virtually limitless faded, it became apparent that protection of these resources must be considered during the planning process. Such consideration was made a requirement of Federal agencies through the Fish and Wildlife Coordination Act, Presidential directives and policies and other authorities quoted earlier.

Fish and wildlife values were elusive and while offering potential for measurement and quantification, procedures for full evaluation did not exist. Faced with the need to consider these resources, the lack of existing quantification procedures and a reluctance to consider subjective evaluation appropriate, resource planning agencies adapted traditional methods to the problem. These traditional methods were based on the hunting and fishing man-day consumptive use concept, the area method which measured the physical area of the various vegetative structure, and the population method which integrated the area method with that of dominant species and their numbers. Using these approaches, fish and wildlife losses were evaluated and compensated for based on provision of either the same amount of hunting and fishing, acre for acre, equal populations, or equal habitats. An agency's views regarding compensation of resource losses could differ depending upon its interests and the method of measuring the loss. These differences in value judgement have led to conflicts between development and environmental agencies which in many cases were to the detriment of the resource and neglected many intrinsic values of the resource as well.

In the opinion of many, the potential existed for the development of a new method which could fully and objectively quantify fish and wildlife resource values. On this basis and in response to the expressed concerns over the adequacy of consideration being given these resources, the U.S. Fish and Wildlife Service initiated design of a new evaluation method. First published in 1974 as the Ecological Planning and Evaluation Procedures (EP^2), they continue to be refined and revised and are presently known as the Habitat Evaluation Procedures (HEP)(F&WS 1979). Refinement and implementation of HEP is presently handled by the Fish and Wildlife Service's Project Impact Evaluation Team (PIE) located in Fort Collins, Colorado.

Dr. Mel Schamberger, National Coordinator of the PIE Team has described HEP as follows:

> "The HEP methodology was designed to provide an objective and quantitative estimate of the value of fish and wild-resources. Habitat quality and quantity are integrated in a single index value called habitat units, based on measurable criteria in the habitat known to be important in providing the life requisites of the fish and wildlife species of interest. ... The difference between with-project and without-project index values demonstrates the magnitude of the project." (Schamberger 1979)

TECHNICAL VERIFICATION

Since the introduction of the HEP concept in 1974, the Fish and Wildlife Service has continually worked through various means toward its verification as a technically sound and objective process. With the establishment of the PIE team in 1977, this effort was intensified greatly. In conjunction with the Corps of Engineers and other cooperating agencies, testing programs have been established in which HEP analysis is conducted concurrent with more traditional evaluations on active resource development studies. An initial testing program which involved sixteen case studies revealed a wide range of opinions concerning the pros and cons of HEP. Preliminary results indicate that several studies were not appropriate, and that future efforts should focus on fewer, but representative studies and projects (Army Corps 1978)

The establishment of the PIE Team assembled some of the best available expertise to review and revise the procedures through analysis of test applications, state of the art refinements and interagency review. The PIE staff also disseminate the HEP concept and techniques throughout the scientific and academic community by way of publications and presentations. Numerous contracts have been let by PIE with academic institutions both for development and verification purposes.

ACCEPTABILITY

A crucial test of any evaluation method is its acceptance by the scientific community, wildlife oriented organizations and the various agencies involved with resources development and protection. The Corps of Engineers in response to the mandate for greater consideration of fish and wildlife resources, has utilized HEP but only when accompanied by traditional evaluation, and continues to test the assumptions upon which it is based and the techniques involved.

In September 1977, the Fish and Wildlife Service invited the Corps to assign staff support to the PIE Team. In response to this request, the Corps initiated in September 1978, a program through which experienced water resources planners were assigned for consecutive 90-day periods to the PIE Team. The authors of this paper completed the first two of these assignments. This program has provided the Service with needed planning expertise during the development of the HEP Manual. The on-site arrangement has also proven mutually beneficial in enhancing interagency coordination on HEP related activities. Other Federal agencies including the Soil Conservation Service, the Bureau of Reclamation and the National Marine Fisheries Service are also assisting the PIE Team and evaluating HEP as an appropriate means of quantifing fish and wildlife values.

IMPLEMENTATION

One of the primary concerns with the acceptance of methods such as HEP is their usefullness and ease of implementation within an agency's specific planning procedures. The current revisions of HEP are directed toward enhancing it's use as a planning tool. This usefulness as a planning tool is dependent upon the ability to generate predictive data of appropriate detail at selected points in the planning process. To accomplish this, the lead planning agency must likewise provide timely and accurate inputs to the Fish and Wildlife Service as well.

The Corps of Engineers is presently developing a conceptual integration of HEP into its planning process, This effort is currently directed toward the input requirements and output capabilities of HEP and their relationships to planning data and needs. While this complex integration is not yet complete,several aspects are clear:

1. Development of an acceptable and adequate base condition is dependent upon an exchange of information and generation of data from both the HEP and other planning studies;

2. The identification of significant fish and wildlife resources must be an early HEP output based on delineation of the study area by the lead planning agency;

3. The projection of with and without project conditions must be fully coordinated with study participants. Common assumptions and projections must be used throughout by all involved agencies;

4. HEP must provide the timely characterization of fish and wildlife impacts for each selected evaluation species for each alternative considered. The timeliness will permit significant adverse impacts to be properly addressed through the early recognition and employment of mitigation measures. It must be understood however, that all alternatives are evaluated under other criteria as well, and trade-off and sensitivity analysis performed;

5. HEP analysis must identify and quantify any residual unavoidable losses for which compensation may be required;

6. All preceeding must be accomplished within study funding, timing and manpower constraints.

Theoretical integration of HEP with the planning process in itself is not sufficient to document and establish HEP as a single appropriate method. As field planning may vary from theoretical concepts, extensive field testing is necessary. To this end the Corps of Engineers has undertaken a nationwide effort to identify several active studies which would be suitable test cases for HEP implementation. Studies are currently being selected to represent each of the three stages of planning activity and various geographical locations. In this manner, the program is being designed to provide a comprehensive field test of HEP within a reasonable time frame.

DATA

A problem basic to the initial HEP process was the subjective nature of the data developed. Field evaluation was not subject to established criteria and replicability was difficult to establish. In response to this problem, the Fish and Wildlife Service has undertaken the development and publication of a series of Habitat Evaluation Criteria Handbooks. Individual handbooks will be prepared for each four digit ecoregion as described by Dr. Robert Bailey of the U.S. Forest Service (Bailey 1978).

The handbooks will contain data bases for 50 terrestrial species and will include a description and list of the habitat types found in the ecoregion. Also included in the handbooks will be a narrative description of habitat requirements for each species based on literature review and professional opinion. Habitat requirements to support each species life requisites will be displayed on index graphs by indicating the relationship between habitat characteristics and habitat suitability index (HSI) values (Coffee 1979). A similiar regionalized handbook approach for aquatic systems is also proposed.

TRAINING

Effective implementation of a quantitative process such as HEP is dependent upon the familarity with the process by those charged with application. Recognizing this as a critical factor in development of the method and demonstration of it's validity, the PIE Team is currently preparing a comprehensive training package that will accommodate general and technical audiences. The training package will consist of seven slide-tape modules and associated manuals to be presented in a workshop format with lecture and extensive in-depth discussion following student viewing. The selection of specific modules to be presented at workshops is to be based on the level, interests and needs of the students.

In light of the interactive role of the procedures and the need for resource development agency planners to be famailiar with the process the Corps and other agencies are actively participating in the preparation of the training program. When complete, and following a series of initial presentations, the PIE Team will distribute the training package to Fish and Wildlife Service regional offices and to appropriate offices of other agencies who will schedule and conduct the actual field level workshops.

CONCLUSION

In response to societal demands, Federal resource development agencies have been faced with significant changes in their planning procedures. The mandates by policy and directive have resulted in development of planning processes designed to consider broader interrelationships and develop and analyze a wider range of alternatives in the decision-making process. As this approach demands a new sophistication in resource development planning, it likewise creates additional resource data requirements. New methods are needed to quantify values through objective, valid and accepted procedures.

The U.S. Fish and Wildlife Service through development of the revised Habitat Evaluation Procedures is working toward this goal in the critical area of fish and wildlife resources. Success may provide a lessening of the need for mitigation and ultimately compensation, through the development of more environmentally sensitive project designs. Prior to achieving the goal, however, agencies such as the Corps of Engineers and others must verify that the procedures are valid and that they meet the established criteria and the needs of the agency. This paper has reported on these needs and the efforts being made to satisfy them. While much remains to be done, these interagency efforts reflect a new spirit of communication and coordination which has gone far toward reducing the need for traditional advesary roles, and points to ultimate benefits to both the resources and the public.

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Interdisciplinary Developmental and Ecological Assessment: A Prerequisite to Effective Design of Environmental Mitigation[1]

Donald R. Dietz[2]

Abstract.--Mitigation efforts must be based on detailed knowledge of development plans and predicted environmental consequences by a multidisciplinary team of specialists. Impacts on biotic components and systems are transported mostly by abiotic vectors i.e., air and water and thus impact evaluation and mitigation must be based on valid multifunction experimental designs.

INTRODUCTION

Wildlife mitigation is too often only a myth and at best is usually misleading. All too frequently, wildlife mitigation programs are ill-conceived because "wildlifers" plan, conduct and evaluate these programs from an "ignorance" base. The fault lies mostly with the limited purpose of most organizations and the methods used to mitigate for wildlife impacts.

Effective mitigation must be based on both a knowledge of the exact development plans for an area and on adequate ecological knowledge. This paper describes the interdisciplinary approach used by Geological Survey's Area Oil Shale Supervisor (AOSS) in managing the Federal Prototype Oil Shale Lease Tracts in Colorado and Utah. The author credits portions of the concepts discussed to my co-workers in the Area Oil Shale Office, the Oil Shale Lessees and various environmental contractors associated with environmental and operational activities on the Lease Tracts. Special acknowledgement is given to the following coworkers for their review and assistance with this manuscript: Glen A. Miller, Hydrologist; Miles D. LaHue, Environmental Specialist-Air Quality; and Lawrence K. Barker, Chemical Engineer, all of the USGS-Conservation Division, Area Oil Shale Office, Grand Junction, Colorado.

THE FEDERAL PROTOTYPE OIL SHALE LEASING PROGRAM

A brief summary of the Federal Prototype Oil Shale Program will form a basis for better understanding of the monitoring and mitigation program.

In 1973, the U. S. Department of Interior leased four 5000-acre tracts for commercial oil shale development. This program was designed to test the feasibility of producing shale oil commercially and to determine the associated environmental costs and impacts of commercial operation. Two years of baseline data and two additional years of precommercial phase monitoring have been completed. The lessees have submitted both Detailed Development Plans (DDPs) and Monitoring Programs. Both have been approved subject to specific conditions including stipulations that the monitoring and mitigation programs be kept flexible and dynamic.

Presented herein are some of the problems and proposed solutions encountered in developing a workable and meaningful monitoring and mitigation program for the lease tracts.

THE OIL SHALE REGION

Although the concepts related here are believed to be applicable across a wide variety of habitat types, the characteristics of the oil shale region helped mold the program into its present form. The Colorado lease tracts are located in the Piceance Basin while the Utah tracts are found in the adjoining Uinta Basin to the west. Physiographically, the basins are arid plateaus that have been greatly eroded and are intricately dissected by intermittent streams. The region is characterized by broad, flat divides which drop off over covered slopes, to narrow alluvial valleys. Alluvial fans spread from the mouth of many tributaries of the major stream channels.

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[1] Paper presented at Mitigation Symposium, Colorado State University, Fort Collins, CO, July 16-20, 1979.

[2] Oil Shale Coordinator, USFWS, Reg. 6.

Of major geologic interest are the Green River and Uinta formations of Eocene age which contain more than a trillion barrels of shale oil in the form of kerogen-rich marlstone (Weeks, et al., 1974). The two basins are separated along the Colorado-Utah border by the Douglas Creek arch.

The oil shale area of the Intermountain Region is characterized by hot summers, cold winters, abundant sunshine, low relative humidity, light precipitation and large diurnal temperature variation. The growing season averages about three months in the basins to less than two months in the higher mountains nearby. Temperatures range from 40°C to -40°C and average about 7°C. Annual precipitation ranges from about 30 cm to 64 cm according to elevation. Air quality is generally good as is visibility (Weeks, et al., 1974).

The mule deer herd inhabiting the Piceance Basin is world famous because of its large size and popularity with sportsman. Mule deer are characteristic of large ruminants that depend on mountain brush species such as bitterbrush, mountain-mahogany and serviceberry as basic diet items. The higher basin rims are vegetated with aspen, pine and fir, but basin-wide the predominate vegetation is pinyon-juniper and sagebrush. In the more xeric areas of the Piceance Basin and in most of the Uinta Basin, desert and salt-desert shrubs predominate along with several species of juniper. Greasewood is found along drainage channels in both basins.

The region provides grazing for cattle and sheep as well as for feral horses. Many birds and mammals frequent the region either as residents or as migrants. Although aquatic resources are limited, several threatened and endangered fish species inhabit portions of the major rivers which are the Colorado, Green and White (Dietz, et al., 1978).

DEVELOPMENT

The success of mitigation programs is strongly correlated with our degree of knowledge of the development processes planned. The two Colorado tracts are being developed by modified in-situ retorting processes and for development of the two Utah tracts by room-and-pillar mining with above-ground retorting.

The modified in-situ process involves underground mining and underground retorting to produce shale oil. About 20% or more of the oil shale within a given retort is directly mined and may be retorted on the surface. The remainder is rubblized in place to create an underground retort. This provides the permeability needed for flow-through of the injected gases which maintain combustion and also for the removal of the products formed. Retorting rate is controlled by regulating the volume, pressure, and oxygen content of the injected air; by diluting steam or recycled gases and by varying the back pressure on the gas outlet shaft.

Burners are then placed on top of the rubble, and air is either pulled through from the top by exhaust blowers or pushed by the use of air compressors. The burners are turned off when reaction temperature (900°F) is reached. Steam or other gases are then introduced along with air to regulate burning at a desired temperature and also to control the rate of flame-front advance.

Product oil and water which condense on the cooler, unretorted shale at the bottom of the retort chamber are pumped to the surface. Off-gases are exhausted by blowers which carry it to a scrubber system located above ground. The gas is contacted there with a circulating water stream which removes entrained dust and oil particles. The scrubbed gas is purified by compression which removes the oil and water. Sulfur compounds are removed by a Stretford or similar process. The purified gas may then be used to fuel low-Btu/lb boilers to produce steam or possibly to fuel gas turbine electric power generators. The oil will be shipped to existing refineries by pipeline. Shale oil is an ideal feedstock for making the scarce diesel and home heating fuels.

Of course, plans must also be made for the roads, utility corridors, surface facilities and the wide variety of support activities required with massive resource development activity.

IMPACT ASSESSMENT

It appears quite obvious that before mitigation programs for wildlife and other environmental impacts are planned, it is absolutely essential that the nature, location and duration of the impact be forecast.

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[3] U. S. Bureau of Land Management, Oil Shale Lease, Tract C-a, Serial No. C-20046, 1975.

Most leases for energy development on federally owned land require an Environmental Impact Statement, either site specific or as an "umbrella" document. The environmental stipulations of the oil-shale lease state: "The lessee shall conduct the monitoring program to provide a record of changes from conditions existing prior to development operations, as established by the collection of baseline data."[3] Conditions for approval of the lease-required detailed development plan also state: The environmental monitoring plan shall be revised as needed, based on the analysis of the final baseline report--submitted for review and approval by the Mining Supervisor prior to commencement of commercial development."[4]

The lessees were required to conduct a two-year baseline program before beginning any construction. While the two-year baseline program was intended to establish "baseline conditions" in the natural environment from which significant perturbations could be measured, it became evident that treatment-control designs are necessary to separate development effects from random natural changes. This necessity is especially valid for dynamic parameters such as faunal populations (Dietz, et al., 1977).

MONITORING AND MITIGATION GUIDELINES

To meet the objectives of the Area Oil Shale Office (AOSO), guidance was needed to:

(1) determine the impacts of mine development on the environment,
(2) control and/or mitigate for detrimental effects of development and
(3) revegetate and reclaim disturbed sites in a timely manner.

The following discussion summarizes a set of guidelines developed by staff specialists at the AOSO to assist in the management of the oil shale lease tracts on the Colorado C-a and C-b sites. The suggested guidelines, while designed for oil shale development, would also generally apply to other resource development programs with similar goals and objectives.

The prototype program is unique in that the interdisciplinary data collected on about 20,000 acres must be used to predict the potential environmental impacts on several million acres of land in Colorado and Utah. Because of this charge, these monitoring programs must address much more than specific site impacts and mitigation. The scope of the program allows for regional impact projections by the Department of Interior for a mature oil shale industry.

The following procedures are recommended for conducting monitoring and/or mitigation programs. The AOSO followed a somewhat similar stepwise approach with the Oil Shale tracts; however, hindsight now permits certain improvements.

The first major decision is how to conduct baseline studies. Baseline studies should do at least two things --(1) describe existing environmental conditions and (2) provide a basis for subsequent monitoring and mitigation programs. Most baseline studies, unfortunately often concentrate on the former and disregard the latter. This is an expensive mistake - both financially and environmentally because to provide a calibration for change, careful and detailed experimental designs should be developed based on (1) mining and other development plans, (2) their predicted effect on environmental components and processes and (3) best "state-of-the-art" methods for determining effects of development on these important components and processes. In brief, coupling baseline sampling design to the detailed mining plans provides the mechanism for selecting appropriate field and statistical methods to measure resultant environmental impacts. Mitigation programs can then be designed which have a good knowledge base because it is known what disturbances will take place (where and when) and what environmental factors will probably be affected (how and for how long).

This approach of marrying mitigation and monitoring plans to mining and development plans, as they will affect a specific site and its associated ecosystem, calls for a multidisciplinary effort. This team requires engineers to understand how the mining development activities will change the above and below surface physiography. Environmental geologists and soil scientists must translate these engineering data into potential impacts or perturbations to the physical environment. Air quality and water specialists, as well as hydrologists and meteorologists, must further translate how the pollutants and/or other effluents perform as vectors transporting airborne and waterborne constituents from the physical environment to the biotic environment - both directly and indirectly. At this point, the ecologist, biologist, range scientist, and reclamation specialist must predict and determine which biotic components and processes will be affected. These team members must select the most appropriate parameters to monitor and the methodology that will permit the best evaluation of a specific mine development action on a biotic parameter and/or system of abiotic-biotic components.

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[4] Peter A. Rutledge, Area Oil Shale Supervisor, written communication, August 1977 and September 1977.

The draft guidelines for monitoring the effects of oil shale development proposed by the AOSO are presented here as an example of how environmental impacts can be mitigated. Adequate knowledge of the site specific detailed development plans and baseline data on abiotic and biotic parameters and their relationships is necessary.

AOSO MONITORING PROGRAM

The AOSO interdisciplinary team of specialists determined the following steps and procedures were necessary to assure an effective environmental monitoring program would be initiated on the prototype lease tracts:

A. Perform Baseline Studies
   1. Perform general ecological survey of site and surroundings.
   2. In conjunction with mining and development plans, determine purpose, objectives, experimental design and rationale for overall monitoring/mitigation program.
   3. Select both short term and long term study or sample sites. They should utilize the treatment-control concept where required and also be designed to account for temporal and spatial differences. Obvious strata should be recognized and delineated in the field design.

B. Describe resource development actions.
   1. Prepare detailed plans and maps of all known development actions.
   2. Determine location, duration and intensity of all development actions.

C. Estimate perturbations to abiotic and biotic components and processes for development actions.
   1. Prepare itemized list of all development actions segregated into significant individual activities and the corresponding perturbations to the environment.
   2. Locate and designate a time frame for the impact or change to environmental entities.

D. Prepare preliminary mitigation plan.
   1. Based on expected impacts to environmental components and processes (A. above) from planned development actions (B.) and their expected environmental perturbations (C.), draft actions to mitigate detrimental effects.
   2. Mitigation plans should concentrate in time and place for the adverse impacts judged to be important and significant.

E. Prepare monitoring plan for potential perturbations and mitigation efforts.
   1. Monitoring plan should be designed to follow trends in those parameters judged to be important ecologically, economically and politically.
   2. Selected parameters should also be judged to be potentially and significantly impactable.
   3. Selected parameters should be measurable and impacts from development separable from random environmental effects.
   4. The expected analytical analyses should lead to effective and relevant management decisions regarding significance and direction of impact.
   5. Data analysis should provide a timely basis for deciding if, when, how and for how long to mitigate an adverse impact.
   6. The mitigation monitoring program must be the basis for evaluating the success (or failure) of the efforts to prevent and/or alleviate environmental impact or degradation. Therefore, it is essential that evaluation methods be statistically oriented inasmuch as is practicable.
   7. The monitoring program must be designed to integrate data from the various disciplines, determine and track the multitude of intra- and inter-relationships among biotic and abiotic variables and to permit the formulation of prediction models which must provide the basis for long term management decisions. Prediction and simulation models may be the most powerful tool the AOSS will have regarding feasibility of the Prototype Program and the Department of Interior in regard to future leasing programs.

DEVELOPMENT ACTIONS AND POTENTIAL ENVIRONMENTAL PERTURBATIONS

The monitoring guidelines prepared by the staff of the AOSO are specific for the Federal Prototype Lease Tracts, but the concepts and rationale are widely applicable. Development actions which describe the engineering, construction, mining, processing, transporting and other actions are listed in matrix form along with the potential perturbations to the environment.

For example, the modified in-situ method of oil shale extraction requires mining operations for shaft sinking, drift development and below surface retort construction. These development actions have the potential for causing the following perturbations to the environment: create surface disturbance, create noise, create dust and particulates, emit gases, alter groundwater quantity and quality, alter surface flows, create chemical leaching, create water effluents, create seismicity and subsidence.

Of special interest to wildlife managers are the potential perturbations of overburden and shale handling and disposal. Besides the fact that these actions will definitely create a surface disturbance that is likely to form a wildlife barrier and create noise,they are also a potential source of air, water, and soil pollution.

Aquatic specialists are concerned about the potential perturbations resulting from mine water programs which include dewatering, reinjection, mine waste water, surface discharge and evaporation. Of major concern is the potential for creating odors, emitting gases, altering runoff, creating erosion, altering surface and groundwater quantity and quality, creating chemical leaching and water effluents and creating subsidence. Where mine dewatering is necessary, the effects of dewatering and water handling procedures can produce widespread effects long before actual production operation begins.

Once a development action and its associated potential perturbations have been identified, the selection of biotic and abiotic parameters for measuring the impact, if any, must be done. A plan for mitigating the more serious perturbations should be developed even though no actual data have been collected. Subsequent data analysis will provide the basis for modification of the mitigation (and monitoring) programs.

PARAMETER SELECTION, MONITORING AND ANALYSIS

As previously mentioned, the baseline data collection program must not only describe existing environmental conditions, but must also provide a pre-treatment (development) calibration of important parameters. This program should also establish information on variability of parameter values over time and space and permit selection of most appropriate experimental design. Preliminary control plots should be established for dynamic parameters. Various distinct strata should be delineated and considered in the experimental design.

Parameters must be selected for both the environmental monitoring program and the mitigation program so that trends and significant changes and/or impacts can be evaluated. Examples of some important parameters selected for the oil shale monitoring program follow:

Fauna
- Deer distribution and density
- feral horse distribution and density
- small mammal composition and density
- avifauna distribution and density
- threatened and endangered species observations
- general wildlife observations

Flora
- plant condition and stress
- plant cover and density
- plant production and utilization
- plant chemical composition
- threatened and endangered species occurrence
- vegetation types and stage of succession

Aquatic
- benthos biomass and diversity
- periphyton biomass and diversity
- fish (contingency)

Soil-Site
- elevation, aspect, percent slope
- soil series
- soil depth - A and C horizons
- soil temperature
- soil moisture
- soil pH and conductivity
- soil elements, major, minor and trace

Hydrology
- stream and spring/seep flow and quality
- alluvial water levels and quality
- upper and lower aquifer levels and quality
- sediment characterization

Meteorology/Climatology
- air temperature and relative humidity
- precipitation and evaporation
- barometric pressure
- solar radiation
- wind speed and direction
- inversion
- noise

Air Quality

- sulfur dioxide, nitrogen dioxide, and carbon monoxide
- non-methane hydrocarbons and ozone
- total suspended particulates
- size distribution
- trace elements
- gross radioactivity
- carcinogens
- visibility
- plume transport and diffusion

Many of the above-listed parameters are either directly or indirectly related to one another. Determination of these many forms and degrees of relationships are extremely difficult but are a must in understanding ecosystem processes extant on the tract and prevalent in the oil shale region. A mirror image type matrix facilitates an estimation of important relationships among the parameters - both abiotic and biotic. The most important interrelationships can be studied by various correlation, regression, or other statistical tests. This requires that the parameters be studied for relationships (or used in various models) and be sampled in the same time and location, or at least reasonably so.

EXAMPLES AND SUMMARY

The monitoring guidelines prepared by the AOSO specialists relied heavily on the use of:

(1) Detailed development plans showing large-scale base maps (1"=600') and same scale mylar overlays which are time sequenced and delineate roads, utility corridors, surface facilities, ponds, overburden and raw shale areas, parameter sampling locations, etc.

(2) A matrix comparing development actions with potential environmental perturbations.

(3) A matrix comparing potential environmental perturbation with best abiotic and/or biotic response parameter.

(4) A matrix prepared in mirror image to compare all parameters with each other to facilitate as estimation of important relationships.

With these "tools" to work with, the various staff specialists could predict the environmental consequences of any combination of development action on most of the important components and processes which comprise the abiotic/biotic makeup (ecosystem) of the oil shale lease tracts. We feel this is a must for design of specific as well as integrated mitigation programs for the many development actions which will take place over the life of the active lease.

A significant value of the procedures and concepts just discussed are that they provide a knowledge base to design the field, laboratory and statistical procedures for determining the changes brought on by development and permit a continual review of mitigation progress, including specific successes and failures. The whole process is highly dynamic and, hence, must be designed for the utmost flexibility, but always within the "scientific method."

As an example of how the process operates, consider some of the environmental consequences and hence mitigation needed for a road system for a modified in situ mining operation. The engineering and construction activities will be basically similar for most resource development programs.

Two major items to consider for the transportation system are roads and vehicles. These activities can potentially create a surface disturbance, form barriers for animals, cause collisions, create dust and particulates, alter water quality, etc. The road system should be drawn on mylar overlays, time sequenced so that the location, time and duration of each activity can be predicted for each item of concern.

Each potential perturbation to the environment from the road system should be considered for monitoring and mitigation. For example, surface disturbance (a potential perturbation) resulting from road construction (a development action) can be measured by such air quality and meteorology parameters as: visibility, total suspended particulates and size distribution. The air quality parameter -- total suspended particulates --is related to various abiotic and biotic parameters including stream quality; benthos, periphyton and fish, plant vigor, plant utilization by animals, and animal distribution. Thus, roads as a transporation action can both directly and indirectly affect wildlife populations and their habitat. Experimental designs using these parameters can provide the data needed for determination of significant changes. Correlation-regression procedures can also assist in selecting the factors most responsive to these impacts. Simple models can then be built which will facilitate impact prediction by the staff specialists, thus providing a quantitative basis for management decisions by the AOSS.

Mitigation based on this type of engineering and baseline data, environmental assessment and predicted environmental consequences of the development action has a good chance of succeeding. Where it fails, actual data is often available or can be collected to determine cause-and-effect, thus readily facilitating modification and reevaluation.

For example, a road through unstable site conditions may result in degradation of trout spawning areas. This impact can be predicted by the above procedures and the impact mitigated by such actions as moving the road to more stable site conditions, applying soil stabilizers, planting vegetation buffer strips to filter out sediment or, in case these fail, the improvement of other portions of the stream to compensate for spawning loss.

In summary, it is becoming increasingly clear that the wildlife manager and biologist must utilize all the managerial and scientific assistance available to effectively protect and enhance wildlife values subjected to complex and massive development programs.

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Pre-Impact Process Analysis: Design for Mitigation [1]

Joe C. Truett[2]

Abstract.--A study of physical and biological processes supporting important fish and wildlife species along Alaska's Beaufort Sea coast suggests how petroleum development can proceed with the least possible impact. The study's strategy--process analyses--is generic in nature and is broadly applicable for identifying mitigative measures to accompany many kinds of development. This strategy is preferable to a more traditional inventory-based environmental assessment.

INTRODUCTION

In conservative language, mitigation has come to mean the compensatory measures taken to offset fish and wildlife losses attributable to development. A prevailing view is that the only meaningful way to mitigate such losses is full compensation in kind by providing fish and wildlife production elsewhere. However, as Rappoport et al. (1977) pointed out, mitigation by replacement is often difficult or impossible to attain. In such cases mitigation might be achievable only by requiring the developer to change the design of the proposed development so that fish and wildlife losses will be minimal.

A major obstacle to recommending design alternatives that will mitigate losses is the scarcity of data that show how fish and wildlife will respond to the various development options. Practically speaking, because we cannot reliably predict or assess impacts of many environmental changes, we cannot provide development groups with the information they need to select development options that benefit fish and wildlife. This paper suggests how predevelopment ecological information should be collected, via the impact assessment process or otherwise, when the objective is to determine how developers can mitigate fish and wildlife losses by appropriately designing development projects. First I will point out three ways that conventional studies obstruct the collection of appropriate data, and recommend remedial measures. Then I will show how a study that has applied these recommended options was able to suggest mitigative courses of development action.

OPTIONS TO CONVENTIONAL STUDIES

Conventional impact assessment studies usually fail to provide data that suggest meaningful courses of mitigation, not because the studies were poorly implemented, but because they were improperly designed. Recommended options for three aspects of research design follow.

Baseline vs. Process Studies

Convention: *The primary emphasis of most ecological "impact" studies is to conduct biological baseline surveys to characterize the predevelopment environment.*

Implicit in the baseline study approach is the concept that the distribution and abundance of organisms in an area can be quickly determined, that the knowledge exists to then judge how these organisms are vulnerable to development, and that monitoring studies can be conducted during and after development to confirm that biological populations have (or have not) responded to development as predicted. None of these premises is commonly true, especially given that most baseline studies entail fewer than several man-years of survey effort. In the first place, neither the distribution nor the abundance of many species is easy to document given the usual amount of time and effort. Seasonal and annual variability are major confounding factors in most surveys. Second and more importantly, the knowledge to readily predict precisely how development will affect the species rarely exists and, in any case, cannot be developed from baseline data alone (Thomas et al. 1976, Holling 1978: 4, and others). And most disappointing of all, it is extremely difficult or impossible in most monitoring situations to relate post-development changes in populations to the causative mechanism and thereby to sort man-caused change from normal fluctuation (Dietz 1976, Holling 1978: 26, Verma et al. 1978, and others). Recent scientific opinion concurs with this view that baseline surveys of system components produce few data useful for impact assessment (Reichle 1975, Odum and Cooley 1976, Rappoport 1977, Holling 1978: 3,4).

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[1] Paper presented at The Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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Suggested Option: *The emphasis of studies designed to formulate recommendations for mitigation should be on ecosystem processes, or how the parts of the ecosystem function and interact.*

Advantages of studying system processes have been recently pointed out by several authors. Verma et al. (1978), quoting Zar (1975), state that functional relationships between ecosystem components must be evaluated in order to predict the effects of altering any of the components. Reichle (1975) likewise contends that all but very direct impacts can be predicted only by knowing something about system processes. Odum and Cooley (1976) and Holling (1978: 28) maintain that a few measurements of selected functions of ecosystems will reveal much more about how the system will respond to stress than will a host of component factor measurements.

Definition of Objectives

Convention: *Most ecological "impact" studies have objectives that are broad and ambiguous.*

The National Environmental Policy Act (NEPA), guidelines of the Council on Environmental Quality (CEQ), and many Federal agency guidelines are very broad and ambiguous in their requirements for impact studies. NEPA and CEQ guidelines, for example, requi a "description of the pre-development baseline environment". Other agencies may, in stating their requirements, us descriptors such as "wildlife and habitat conditions", "fauna and flora", "ecological baseline conditions", or "ecosystem interactions". Such terms imply a broad and sweeping view. Invariably such generalized and broad objectives require extensive interpretation by the investigators and result in data products that are inconsistent and only coincidentally useful. For, as Holling (1978: 4) points out, the concept that any good scientific study contributes to better decision-making is a myth.

Suggested Option: *The scope of assessment studies must be severely restricted if data sufficient for predicting impacts and recommending mitigative actions are to ensue.*

The most commonly recommended manner of restricting the scope of inquiry is to limit the system components or processes to be examined. Verma et al. (1978) discuss several criteria for selecting parameters to be studied from the broad array that is normally available. Kerr and Neal (1976) point out that the aim should be to select for study the minimum number of variables necessary to account for the ecological behaviors of interest. Holling (1978: 14, 25) emphasizes the necessity of addressing only a few high-profile components ("indicators") that are relevant to the interests of data users. Odum and Cooley (1978) have found it effective to combine a few judiciously selected system properties with a few "red flag" components (factors or species) that are of special concern.

Similarities Among Systems

Convention: *There is a tendency for*

each impact assessment study to be conducted in isolation, as if data from other times and places are not relevant.

This view is engendered by the baseline study concept, which assumes (perhaps correctly) that each area is unique in its composition of components. Because of this idea, scientists are extremely hesitant to extrapolate either ecological information or predictions of impact from one area to another. Consequently, assessment studies and the resulting mitigative recommendations are not able to profit by what has been learned elsewhere and must depend largely on their own meager time and financial resources.

Suggested Option: *A major advantage of looking at processes instead of components is that processes are frequently similar among regions and situations, and extrapolations are warranted.*

Available evidence supports this view. Reichle (1975) notes that there are recurring patterns of function among systems. Kerr and Neal (1976) point out that both physical and biological processes in some systems exhibit important regularities, and that ecological processes appear to be entrained to the inherent (and predictable) scales of the physical environment in which they occur. Odum and Cooley (1976) believe, furthermore, that specific and predictable types of interactions occur between particular classes of ecosystems and particular classes of perturbations. All these authors believe that extensive extrapolations among situations should be possible on the basis of observed similarities of processes among systems.

IMPACT ASSESSMENT AND MITIGATION IN NORTH ALASKA: A CASE STUDY

The Bureau of Land Management (BLM) is funding, through the Outer Continental Shelf Environmental Assessment Program of the National Oceanic and Atmospheric Administration (NOAA/OCSEAP), environmental studies in Alaska to assess the impacts of petroleum development in continental shelf waters. This program has had the luxury of conducting environmental studies well in advance of major development; as a consequence, the findings of the studies are being used in the formulation of stipulations to regulate development. The data from these assessment studies, in essence, show how to mitigate the impacts of development.

One of the studies being conducted in Alaska's Beaufort Sea is called the Beaufort Sea Barrier Island-Lagoon Ecosystem Process Study. The geographical focus of this study is in the Simpson Lagoon-Jones Islands area west of Prudhoe Bay, and involves scientists from several research disciplines. The study has attempted, among other things, to fashion its research approach according to the options presented above, that is, to address processes rather than components, to focus investigation on a few important objectives that could reasonably be addressed, and to expand the usefulness of the findings by viewing them in a broader geographic and ecologic context. To date a number of suggestions for mitigating impacts by appropriate selection of design options have been formulated. The following discussion briefly summarizes the study's research strategies and suggests mitigative measures to be recommended as a consequence of the findings. (It should be noted that this study used an adaptive systems modeling approach (see Holling 1978) to structure interdisciplinary communication, to help formulate disciplinary research objectives, and to promote maximum use of research findings. However, the modeling aspects of the program will not be discussed in this paper.)

A Study of Processes--Why and How

The decision to study ecosystem processes in this study rather than to simply describe system components (species) was made by NOAA/OCSEAP planners, who saw the limited usefulness of baseline data. (Note that other ongoing OCSEAP-funded investigations in the Beaufort Sea have other objectives, including the collection of baseline data.) These planners specified that the study should address the processes related to food-web and habitat dependencies of organisms that were of interest to society because of their recreational, commercial, or subsistence utility. OCSEAP furthermore specified that, among the array of processes important to these selected species, only those processes judged to be vulnerable to development were to be given intensive examination. (It should be noted that, although the required emphasis of the study was on the processes, periodic surveys of selected species and physical components were necessary because processes frequently could not be measured directly but had to be inferred from component measurement data.)

A Strategy for Focusing Research--"From the Top Down"

Within the scope of investigation specified by OCSEAP the investigators themselves established a strategy for further reducing the array of items to be studied. This strategy involved a sequential series of decisions as follows:

1) A limited number of system components (species) were identified at the outset as "key species" (equivalent to the "indicators" of Holling, the "red flag" species of Odum and Cooley). A few changes were made in the list as the study progressed and provided additional data. The species ultimately studied as key species were birds (oldsquaw ducks, red and northern phalaropes) and fish (arctic char, arctic and least cisco, arctic cod, fourhorn sculpin)--a total of eight.

2) The major pathways in the food chain of each key species were documented to the extent possible, beginning with the species itself and proceeding step by step down the chain. A major emphasis of the study was to supplement what was already known about food chain dependencies of important species so that a clear picture, from nutrient and carbon (energy) source to key species, emerged. Tentative conclusions are that major pathways in food chains are relatively few and typically involve (a) the key species eating primarily the epibenthic crustaceans--mysids and amphipods, (b) the mysids and amphipods depending for energy mainly on *in situ* primary production rather than on detritus, and (c) the nutrient sources for this primary production coming from both terrestrial and marine environments. It should be noted that this strategy of constructing food chains "from the top down" did not result in a complete ecosystem food-web description, but eliminated consideration of those nutrient cycles and energy pathways that did not directly involve a key species. Examples of system components that could be expected to be important links in the food chain but that now appear not to lead to key species were the abundant peat detritus in the system and the infaunal benthos.

3) As the key species and their major food chain organisms were identified research was structured to study the major physical, chemical, and biological processes that maintained habitats optimal for each key and food chain species. A few characteristic processes were found to be important in regulating habitat quality for many of these species. We found, for example, that the annual dispersal of one important prey group (mysids) depended on existent water circulation regimes. It also appeared that the rapid growth of these mysids might be dependent on the relatively high temperatures of lagoon waters in summer, a situation fostered by the somewhat restricted exchange between lagoon and ocean waters because of the impediment of the barrier island chains.

In summary, as a consequence of this strategy of elimination of options for study, investigative efforts concentrated on only those physical or biological processes that were directly or indirectly (through effects on the food chain) important to the support of key species and that were judged to be susceptible to alteration by some of the development options possible.

A Look at Other Systems--Parallels and Extrapolations

We are now looking beyond our study and at findings about the ecological functioning of similar systems. Although it is yet too early to unequivocally confirm how many parallels exist between our area and other areas, there is very strong evidence that there are many. (Obviously there are differences also; otherwise, process-type data could be universally applied with no requirements for site-specific investigations.) Examples of probable similarities between Beaufort Sea coastal systems and some other coastal systems are as follows:

The coastal lagoons appear to be "nursery areas" for trophically important species of epibenthic invertebrates (e.g., mysids).

These mysids (and perhaps other epibenthic invertebrates) appear to take advantage of prevailing current regimes to accomplish critical migrations within the nearshore region.

The growth rates and consequent secondary production of some of the important epibenthic invertebrates may be temperature-regulated and therefore controlled by water quality in summer in the nearshore region.

The behavioral and life-history patterns of some of the fishes appear to correspond in some cases to those of fishes occupying the same types of estuarine situations in other parts of the world.

Anadromous fish in their coastwise migrations concentrate in very shallow waters, principally near the mainland.

Patterns of nearshore circulation and estuarine-marine water exchange appear to parallel those occurring in other estuarine systems.

The barrier island-lagoon systems have been formed by intrusion of the sea onto low-lying areas behind topographic highs; the islands themselves are largely reworked remnants of mainland features and appear not to be nourished extensively by materials transported from elsewhere.

Because of such similarities, our utimate understanding of the functionig of the nearshore Beaufort Sea eosystem is likely to be much greater tan it would have been had we viewed r findings in relative isolation.

Recommendations for Mitigation

Our findings have a number of plications for the design of offshore d coastal development projects. Some amples of tentative recommendations r mitigative action at the project sign stage are as follows:

Causeways constructed in the nearshore region should be designed such that the general circulation and water mass exchange patterns in the shallow nearshore regions are not greatly altered, and so that routes of entry and exit of epibenthic invertebrates and fish to the lagoon systems are not severely restricted. However, small-scale changes in these processes are likely to be innocuous.

2) Since anadromous fish appear to migrate along the coast in very shallow waters, special provisions should be made to allow fish to readily by-pass long, seaward-extending causeways.

3) Since birds concentrate in the lagoons, on the islands, and along the shores at very specific times in summer and early fall, activities that would disturb the birds in these areas need be curtailed only for short and precisely-identifiable periods.

4) The lagoons behind the islands should be maintained as shallow, protected basins for it is probably this topographic conformation that makes the nearshore areas most useful to the birds and fish and their prey.

5) Barrier islands should not be extensively mined as sources of sand and gravel for construction purposes, for the islands will probably not be regenerated by currently-functioning physical processes.

6) The local effects of non-persistent contaminants introduced as a consequence of development may be short-lived in most cases unless huge areas are contaminated, because both the key species and their food-chain components are highly mobile (they may repopulate an entire lagoon system within days or weeks) and therefore are able to rapidly reinvade areas once such contaminants become inactive.

CONCLUSION

In summary, based on our experiences in the Beaufort Sea study, we think that realistic recommendations for mitigative actions at the project design stage can be made on the basis of predevelopment studies if (1) investigations during these studies are at the process rather than the component level,

(2) the scope of research is narrowed at the outset to focus on a few important species and/or ecosystem properties, and (3) extensive comparisons are made with other ecosystems, and interpretations of findings are, in part, judiciously based on what has been found elsewhere.

ACKNOWLEDGEMENTS

This study was supported by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, under which a multi-year program responding to needs of petroleum development of the Alaskan continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

Special thanks go to Gunter Weller, David Norton, and Herbert Curl, Jr., who suggested the use of the process study and who have supported the Barrier Island-Lagoon program since its inception.

Appreciation is also extended to Carl Walters and his associates at the University of British Columbia; to Brian Matthews, Jan Cannon, Sathy Naidu, and Don Schell at the University of Alaska; to Chris Mungall of Kinnetics Laboratories; and especially to Stephen Johnson, Peter Craig, William Griffiths, and all the other biologists of LGL Limited and LGL Ecological Research Associates who participated in the program.

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Evaluation of Fluvial Trout Habitat in Rocky Mountain Streams[1]

N. Allen Binns[2] and Fred M. Eiserman[3]

Abstract. A Habitat Quality Index (HQI) was developed to quantify fluvial trout habitat in Wyoming. As an aid to the mitigation process, the HQI has been used to document and quantify the deterioration of trout habitat and populations caused by man's activities.

INTRODUCTION

Realistic cost-benefit analysis of water
evelopment projects has long been a problem to
ishery workers. Attempts to assign monetary
lues to fishery resources for such analysis
ve not always been satisfactory. However,
cent federal legislation has drastically
anged the planning of water resource projects.

The Water Resources Planning Act (Public
w 89-90) led to regulations (Water Resources
uncil 1973) that both monetary and non-mone-
ry evidence must be considered when analyz-
g project feasibility. These new rules had
ch potential to improve mitigation of poten-
al fishery losses from water development pro-
cts by defining the impact and values to be
pected. As other speakers have pointed out,
sh and wildlife agencies can not develop suit-
le mitigation measures unless they can first
termine the impacts and values involved.

Unfortunately, procedures for non-monetary
asurement of aquatic habitats were primitive
en the new rules were issued and a methodolo-
gap soon became evident. This led to fears
at fish and wildlife interests would be short-
anged. Early attempts to develop a suitable
thodology (Anonymous 1974) were too subject-
e and not realistic when applied to fluvial trout habitat in the Rocky Mountain region. The need for an objective, standard habitat evaluation procedure for that area soon became acute.

Accordingly, a project was initiated by the Wyoming Game and Fish Department to develop a standard procedure for evaluating fluvial trout habitat in Wyoming. This study led to the development of a Habitat Quality Index (HQI), which has been used in Wyoming to quantify trout habitat in streams. Previous reports have discussed preliminary HQI results (Binns 1976, 1978a, 1978b), as well as the development of an improved HQI method (Binns 1979; Binns and Eiserman 1979). The present paper summarizes the HQI method and its applications, with reference to the mitigation of fishery losses.

METHODS

To develop the HQI, a wide variety of fluvial trout habitat was measured and evaluated at 44 study sites in Wyoming. Study site locations ranged from 1,146 m to 3,042 m above mean sea level, while stream gradients were between 0.1% and 10%. Late summer stream width was between 1.4 and 44 m. Average daily flows in those study streams with gaging stations ranged from 0.07 to 14.7 cubic meters per second (m^3/sec) and stream flows in late summer varied from 0.01 to 12.4 m^3/sec.

Data availability and ability to measure were among the criteria used to select, for field testing, 22 attributes characterizing fluvial trout habitat. Although past measurements were available for some of these attributes, most had to be measured in the field. Attribute measurements were made only in August and the first half of September, when flows are low, trout may be stressed by habitat conditions and sampling is easier in Rocky Mountain streams. Attributes were measured and rated according to standardized procedures (Binns 1979; Binns and Eiserman 1979).

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RESULTS

Model Development

Using habitat measurements from streams 1-20, the relationships between the habitat attributes and trout standing crop were explored with multiple regression analysis. This analysis indicated those attributes best related to trout standing crop, which were then used to develop a predictive HQI model (Model I). The overall performance of Model I was good at study sites 1-20 (Binns 1976, 1978a), but additional testing was desirable to demonstrate credibility.

In 1976-77, additional habitat measurements were obtained from 16 new study sites. Model I performed satisfactory at the new sites, but there was need for refinement of the model. Habitat evaluations were often delayed because of the time needed to process the fish food samples required by Model I. Consequently, a new substrate attribute was developed to replace the fish food abundance and fish food diversity attributes. Also, to reduce the impact of any one attribute on the model, the attributes were grouped differently in a new model.

Using the measurements from test sites 1-36, a new multiple regression analysis led to the development of a new HQI model (Model II), which is given by the expression:

$$\begin{aligned}\log_{10}(Y_p + 1) = {} & (-0.903) + (0.807)\log_{10}(X_1 + 1) \\ & + (0.877)\log_{10}(X_2 + 1) \\ & + (1.233)\log_{10}(X_3 + 1) \\ & + (0.631)\log_{10}(F + 1) \\ & + (0.182)\log_{10}(S + 1)(1.12085)\end{aligned}$$

Where:

Y_p = Predicted trout standing crop
= HQI Score
X_1 = Late summer stream flow
X_2 = Annual stream flow variation
X_3 = Maximum summer stream temperature
F = Food index = $X_3(X_4)(X_9)(X_{10})$
S = Shelter index = $X_7(X_8)(X_{11})$
X_4 = Nitrate nitrogen
X_7 = Cover
X_8 = Eroding stream banks
X_9 = Substrate
X_{10} = Water velocity
X_{11} = Stream width

Model Performance

Model II explained 97% of the variation trout standing crop at study sites 1-36. Improved correlation (R = 0.983) and a drop in t sum of squares of residual errors (SSRE) from 43,494 to 17,346 (Binns 1979; Binns and Eiserm 1979) indicated increased model precision. Mo II performed better than Model I, since mean SSRE dropped from 1,550 (Model I, n = 20) to 481 (Model II, n = 36). For sites 1-36, the plot of predicted trout standing crop (Y_p or HQI Score) against measured trout standing cro (Y) was best described by the linear relationship: $Y = 5.978 + 0.926(Y_p)$. At sites 37-44, Model II predicted trout standing crop with satisfactory precision and a low degree of err

When trout standing crop was predicted a sites 1-20 with Model I, the prediction errors ranged as high as 114 kg/hectare. However, wh Model II predicted trout standing crop at site 1-36, no prediction was in error by more than 55 kg/hectare and at only three sites did the error exceed 50 kg/hectare. Since all three streams contained numerous trout, a prediction error of ± 50-60 kg/hectare was less serious than if trout were sparse. Thus, a prediction error of 54 kg/hectare at Sand Creek seemed large, but the predicted standing crop was act ally within 9% of the measured value.

We have concluded that Model II is the better model and is a valid predictor of trout standing crop in Wyoming streams. Model II is the model currently being used for fluvial habitat evaluations in Wyoming.

Trout Habitat Unit Definition

The concept of a standard unit of habita measure called a habitat unit was introduced, but not defined, by Anonymous (1974). So this unit of measurement could be used in our habit evaluations, we defined a trout Habitat Unit (HU) as follows: one trout HU is the amount of habitat quality required to produce an increas in the trout standing crop, of one kg/hectare (Binns 1976, 1978a).

The value (θ_s) of a trout HU was determined using the linear relationship between HQ Score and trout standing crop (Binns 1976, 197 This value represents the amount that the HQI Score changes with a change of one kg/hectare and is equal to the reciprocal of the slope in the linear regression equations for models I a II. For Model I, $\theta_s = 1/0.84 = 1.19$. For Model II, $\theta_s = 1/0.926 = 1.08$. HQI Score is converted to trout HU by multiplying HQI Score by θ_s.

Example of Calculations

As an example of HQI calculations, the trout standing crop and habitat value of the Little Popo Agie River near Lander has been calculated as follows:

Attribute	Field Data	Rating[4]
X_1	CPF = 74% ADF[5]	4
X_2	--	2
X_3	20°C	3
X_4	0.012 mg/l	1
X_7	46%	3
X_8	16%	3
X_9	--	2
X_{10}	1.00 m/sec	2
X_{11}	9.7 m	3

$X + 1 = 5$ $F + 1 = 13$

$X + 1 = 3$

$X + 1 = 4$ $S + 1 = 28$

$$\log_{10}(Y_p + 1) = (-0.903) + (0.807)\log_{10}(5) + (0.877)\log_{10}(3) + (0.1233)\log_{10}(4) + (0.631)\log_{10}(13) + (0.182)\log_{10}(28)(1.12085)$$

$$Y_p = \text{antilog}_{10} 1.788(1.12085) - 1.0 = 68 \text{ kg/hectare}$$

Predicted trout standing crop = 68 kg/hectare
Predicted habitat value = 73 trout HU
Measured trout standing crop = 62 kg/hectare

DISCUSSION

We have used the HQI method with satisfactory precision on a wide variety of Wyoming streams and the method has produced reliable estimates of habitat quality and trout standing crop. HQI estimates of trout standing crop on large streams have often proven quicker, easier and cheaper to obtain than estimates made by conventional fish sampling techniques.

Depending on the needs of HQI users, the habitat evaluation can be presented in kg/hectare, in trout HU, or, when a control stream is available, as a percentage, comparing an impacted habitat against a normal one.

As an example of HQI use, we used Model I to evaluate potential habitat and standing crop changes for Colorado River cutthroat trout (Salmo clarki pleuriticus) that would result from a proposed transbasin water diversion in the North Fork Little Snake River drainage (Binns 1977). Part of the North Fork was affected by a transbasin diversion in 1964 and the present proposal is to extend the pipeline to intercept the remaining tributaries. The resultant reduction in water flows would very likely have a serious negative impact on the trout population. Habitat loss could be severe enough to cause local extirpation in the smaller tributaries and could possibly lead to placement of this species on the threatened or endangered species list.

The problem was to demonstrate this potential fishery loss. To do this, several similar tributaries, including Green Timber Creek, which was affected by water diversion in 1964, were evaluated using the HQI. The study streams are located in adjacent basins of the North Fork drainage.

In spite of a larger drainage area, Green Timber Creek contained only 12 trout HU, compared to an average habitat value of 49 trout HU for Deadman, Harrison and upper Solomon creeks. This difference in habitat value was attributed to the long-term impact of the transbasin water diversion installed in 1964 on upper Green Timber Creek.

Thus, we were able to document the habitat and standing crop deterioration that could be expected from an expanded transbasin diversion in the North Fork drainage. This information proved valuable in project feasibility debates and in obtaining an assurance of adequate instream flows for trout.

We have also assessed habitat improvement potential and documented habitat degradation with the HQI. Fishery managers were then able to quantify trout habitat evaluations in discussions with other resource agencies. For example, Huff Creek, in the Bear River drainage, contains one of the few remaining stocks of the rare Bonneville cutthroat trout (Salmo clarki utah). This drainage has been severely impacted for many years by livestock grazing and by chemical spraying of riparian vegetation.

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[4] See Binns (1979) or Binns and Eiserman (1979) for attribute rating criteria.

[5] CPF = average daily flow during August and the first half of September; ADF = average daily flow during the water year (October 1 to September 30).

An HQI evaluation of Huff Creek identified eroding stream banks, trout cover and water temperature as distressed habitat features. The HQI predicted that habitat improvement, in the form of fencing, stream bank stabilization, and the installation of instream structures, could raise the trout standing crop in Huff Creek from the present 1.5 kg/hectare to 67 kg/hectare. An increase of this magnitude would contribute much to the continued survival of this trout and was a prime selling point in mitigation discussions with land managers.

A further example of HQI use in defining habitat value for mitigation purposes is the Green River below Fontenelle Reservoir. This stream contains a viable and valuable trout fishery, but changes in flow regimes as a result of existing and proposed water development projects could seriously damage the fishery. An earlier study of instream flow needs recommended a maintenance flow between 22.7 and 45 m^3/sec, a winter flow of 14.1 m^3/sec, and a short-term, emergency survival flow of 8.5 m^3/sec (Banks et al. 1974).

HQI measurements obtained in 1978 from the lower Green River predicted a reduction in trout standing crop from 64 to 8 kg/hectare if the discharge regime was changed from 45 to 8.5 m^3/sec. The HQI predictions substantiated the potential negative impact of a reduction in stream flow and gave credence to instream flow recommendations previously advanced (Banks et al. 1974).

Efforts are currently underway to incorporate the HQI into the instream flow needs evaluation program being developed by the Fish and Wildlife Service Instream Flow Service Group.

To calculate trout habitat loss or gain at proposed reservoir sites in trout HU, we used the HQI and Ryder's Morphoedaphic Index (MEI) (Ryder 1965). A study of MEI and trout stock relationships for lentic habitat in Wyoming (Facciani 1977) provided additional data for a comparison with an HQI evaluation of the river to be impounded. When the proposals for the controversial Kendall and Grayrocks reservoirs were evaluated, the HQI-MEI comparison predicted a 42% loss of trout HU at Kendall Reservoir and a 176% gain at Grayrocks Reservoir (Binns 1976, 1978a). The former reservoir would be located on a blue-ribbon trout stream, while the latter would inundate a poor trout stream.

The most important feature of the HQI is that it provides objective and quantitative evaluations of the trout fishery resource in non-monetary terms. Also, the HQI is based on trout standing crop and is derived from measurements of biologically pertinent attributes. T HQI has performed satisfactory in Wyoming wate and we believe additional testing should prove the method usable in other areas, especially i the Rocky Mountain area. The HQI also appears to have definite value for use in mitigation evaluations where there is a potential for los in trout fisheries from man's activities.

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A Computerized Ecological Impact Evaluation Method (CEIEM)[1]

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Composition, diversity and edge parameters were used to develop a computerized method of habitat evaluation for predicting changes to be expected from several alternative futures in a federal water study. Comparison of alternatives indicated project modification requisites and/or compensation/mitigation needs. The method is open-ended. Additional ecological parameters and/or land use planning concerns can be added and applied.

INTRODUCTION

ne 200-mile river reach of the Rio Grande rom Fort Quitman to near Presidio, Texas is n alternating series of about 30 miles of anyons and 170 miles of broad flood plain. ediment from an abused watershed, in the bsence of flushing river flows caused by pstream impoundment and diversion, has lled and is filling the Rio Grande. This hreatens the delineation of the Inter- ational Boundary along much of this river each.

Salt cedar (Tamarisk sp.) has invaded much of the flood plain and river. In many areas this phreatophyte forms pure stands of several hundred acres, oftentimes choking the river. In other areas farming of the flood plain has thwarted the invasion of salt cedar. Farming includes dryland and irrigated cultivation.

The Boundary Preservation Project, sponsored by the International Boundary and Water Commission (IBWC), United States and Mexico, U.S. Section, is a federal project for preserving about 200 miles of boundary between the United States of America and the Republic of Mexico. International treaties and Federal environmental legislation were constraints under which the study participants worked.

The IBWC, U.S. Section, was the lead agency. The Fish and Wildlife Service, Texas Parks and Wildlife Department, National Wildlife Federation, Wildlife Management Institute, and National Audubon Society acted as advisors in the environmental and ecological planning considerations throughout the project study.

EVALUATION METHODOLOGY NEEDS

The Computerized Ecological Impact Evaluation Method (CEIEM) was our response to the need for an evaluation method that was:

Paper presented at The Mitigation mposium, Fort Collins, Colorado, July 16-, 1979.

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(1) objective;

(2) repeatable;

(3) applicable to the problem at hand;

(4) capable of handling several alternative futures in a short time;

(5) adaptable to the available information;

(6) capable of providing relative values for the various alternatives; and

(7) adaptable to the available computer equipment.

CONCEPT, INFORMATION AND CRITERIA

Engel-Wilson and Ohmart (1978) were conducting a one-year ecological study and inventory of the vegetative communities and their faunal inhabitants in the project area for the IBWC. Therefore, a good ecological data base was available for use in the development of the methodology. A vegetative type map had also been prepared by the above authors for use in their study.

Various plants species are known to have different values to a myriad of animal species. In some instances an individual plant species may have several values for several animal species (i.e. food, cover, nesting, denning, etc.). In addition, different plant species have different values to individual animals, as well as groups of animal species.

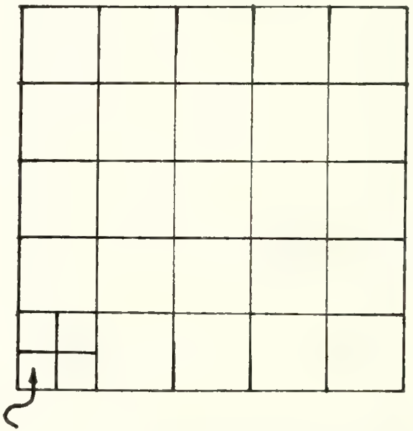
For this methodology, the value factor based on the known number of animal species found in a vegetative community type, was termed composition. Composition values are highest and lowest for those vegetative community types supporting the greatest and least numbers of animal species, respectively. Animal species found in the classes Mollusca through Mammalia were the criteria for this parameter. No value was assigned for the multiplicity of individual animals. Value was given only to the number of species present. The presence of an individual animal within a vegetative community meant that the particular type offered something to the life support of that species. This consideration resulted in all faunal species found, however infrequent, in a particular vegetative community type, being used to derive this parameter value.

Edge, the finite zone separating two dissimilar vegetative types, has long been recognized as beneficial to faunal diversity. This important factor was the second evaluation parameter.

The stability of an ecosystem is dependent on its floral and faunal diversity. The area under study has highly diverse floral complexes as well as unstable salt cedar monoculture. Therefore, the degree of diversity of plant communities was the third parameter used in this evaluation methodology.

It is recognized that the application of physical sciences for analysis of ecological conditions requires an absolute and finite approach. Consequently, data was assimilated so that it could be analyzed by square analytical units. These units should also be of a representative size for land use management if this becomes necessary for planning or project implementation. One primary consideration was that most of the river is narrow (25-75 feet). Quarter-acre square pixels would sufficiently portray the river. The river is the political and ecological focal point in this area. A 25-acre square analytical unit comprised of 100 quarter-acre pixels was determined to be suitable for the ideal finite measurements. Figure 1 is a graphic presentation of the analytical unit and its analytical components.

Figure 1. An Analytical Unit and Its Analytical Components



This resulted in 346,500 pixels contained in 3,465 analytical units. This represented the project area.

A type map was used for digitizing and coding the entire project area by vegetation community down into quarter-acre pixels. If a pixel contained two or more community types then the spatially dominant community type determined the coding. The 346,500 pieces of data (pixels) comprising the project area were keypunched on computer cards for computer input. This information was stored on the disk file of an IBM 1130 computer. The disk file was designed so that each pixel could be located by its specific assigned map coordinate.

PROGRAMMING

Numerous programs were written to perform the necessary evaluations. One program was written to calculate a vegetation composition value for each quarter-acre pixel assimilated into 25-acre analytical units. The computer was programmed, as well, to subtotal the composition value for all of the analytical units.

Additionally, a program was developed to calculate the linear amount of dissimilarity of vegetation types among pixels within a 25-acre analytical unit. The edge value for the analytical units could also be subtotaled.

A value was derived for vegetative diversity by computer analysis of the number of different vegetative community types within each of the analytical units. The value derived also could be subtotaled for all of the analytical units.

The three parameter subtotal values were then combined into what we called "Ecological Health Units" (EHU).

PROJECT ALTERNATIVES

Various project alternatives were simulated by computer and superimposed on the digitized computer map. Each alternative was analyzed by computer, as described above. The boundary preservation alternatives which were considered included:

(1) no action;

(2) monument the boundary;

(3) channel restoration within the existing alignment;

(4) channel restoration with minimum realignment;

(5) channel restoration with intermediate realignment;

(6) channel restoration with complete rectification; and

(7) channel restoration with establishment of a wildlife management area on the United States side.

RESULTS

The value for each parameter by alternative is shown in Table 1. These values are depicted under existing, 25-year and 50-year conditions. They are also shown combined into EHU's. Economic cost are also presented in the table.

Table 1. ECOLOGICAL HEALTH UNITS BY ALTERNATIVES AND ESTIMATED DOLLAR COST - UNITED STATES ONLY

						COST X 1000		
	Years	Composition	Diversity	Edge	EHU	Initial	Annual O&M	Present Worth of 50 year
No Action	0	980	390	210	1580	0	0	0
	25	980	380	200	1560			
	50	1000	340	170	1510			
Monument the Boundary	0	980	410	230	1620	3000	50	3000
	25	990	400	230	1620			
	50	1010	380	220	1610			
Channel Restoration Existing Alignment	0	1000	420	230	1650	4300	500	10600
	25	1010	420	230	1660			
	50	1030	410	240	1680			
Channel Restoration Minimum Realignment	0	1000	420	240	1660	4200	500	10400
	25	1020	410	230	1660			
	50	1030	410	230	1670			
Channel Restoration Intermediate Realignment	0	990	420	240	1650	4700	500	10700
	25	1010	410	230	1650			
	50	1020	400	220	1640			
Channel Restoration Rectification	0	1000	440	250	1690	5800	500	11500
	25	1010	430	240	1680			
	50	1030	400	230	1660			
Channel Restoration Plus Wildlife Management Area on U.S. Side	0	990	460	300	1750	11000	600	16200
	25	1000	460	300	1760			
	50	1020	450	310	1780			

Salt cedar has invaded and continues to spread throughout the flood plain. The "no action" alternative reflects this condition. With "no action" edge and vegetative diversity would be lost. Furthermore, the salt cedar would displace the more desirable thorny shrub communities in many locations throughout the flood plain. The "no action" alternative is the least desirable ecological alternative future.

The second least desirable ecological alternative future would have been "monumenting the boundary". This alternative would result in continued expansion of salt cedar. The slight improvement of this alternative over "no action" is attributed to the edge and diversity from a-line-of-sight between each boundary marker.

The best ecological alternative future is the "channel restoration plus a wildlife management area on the United States side". Composition, edge, and diversity values increase over the "no action" alternative. A portion of this increase is due to the wildlife management area but the majority of the improvement would result from maintaining the river channel on the existing alignment plus a water overflow corridor on each side of the river. "Channel restoration on the existing alignment" with river bank vegetation and water overflow corridors was the alternative selected. Ecological impacts of all other alternative futures fell somewhere between those discussed above.

Costs associated with each alternative are shown in the cost section of Table 1. The least expensive was "no action" but this would not have solved the problem of boundary preservation. The most expensive alternative is that with a wildlife management area. Much of this cost was associated with land acquisition for the management area.

OTHER USES

The system is open-ended. Additional information can easily be programmed. Other parameters such as endangered species, archaeological sites, socio-economics, energy flows, urban planning, development impacts, forestry planning and management, watershed restoration, wildlife and park planning and management, industrial siting, surface mining reclamation, dredge and fill operations, predicting and/or analyzing trends and farm and ranch planning and management are some of the things which can be included for analysis of land use alternatives.

ACKNOWLEDGEMENT

We would like to acknowledge the assistance, criticisms, and encouragements that were offered by all involved in the study. Special thanks are due to Messrs. Bill Sheffield and B. D. King for reviewing the manuscript. We believe it is to the credit of all that a good project was formulated. The plan, when implemented, will preserve the boundary in that river reach while concurrently improving the environment of that area.

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Wildlife Habitat Evaluation and Mitigation[1]

Robert G. Morris and Bruce E. Nichols[2]

Abstract: All land provides wildlife habitat. The quality ranges from very poor to excellent for different species of wildlife. A model for development of a numerical system to analyze habitat was proposed by McCuen and Whitaker (1975a,b). The model was modified by the Delmarva Wildlife Work Group (Soil Conservation Service, 1978a,b). Numerical values based on the Delmarva study are used by the Soil Conservation Service in Maryland to establish existing conditions for wildlife habitat for specific species. This numerical evaluation may then be used as a guide for mitigation purposes by replacement or enhancement.

INTRODUCTION

A system to evaluate wildlife habitat or mitigation and enhancement purposes that s acceptable to the layman and to professionls is needed. The passage of the National nvironmental Policy Act of 1969 and the *Water esource Council's Principles and Standards* ave made it necessary to evaluate wildlife abitat for all federally funded projects that ffect the resource base.

Whitaker and McCuen (1975a,b) analyzed ildlife habitat by inventorying the major omponents, giving each a value, and weighing ts relative importance to groups of wildlife pecies.

The Delmarva Wildlife Work Group (Soil onservation Service, 1978a,b) refined Whitaer and McCuen's procedure for comprehensible nd sound development of data collection and nalysis. The system was designed to provide ndividuals with different backgrounds an cceptable tool of communication. To help ccomplish this, the work group included ishery biologists, wildlife biologists, otanists, foresters, mathematicians, and epresentatives from other professions.

The procedure involved 150 volunteers ho collected data on 19,425 km^2 at 60,000 sites. Personnel from Maryland, Delaware, Virginia state governments, private organizations, and federal agencies established the numerical index values for wildlife habitat. These index values are used by the Soil Conservation Service in Maryland for establishing upland wildlife habitat numerical values.

PROCEDURES

A condition or conditions of an area will limit population growth within the home range. Remove that limitation and the population will increase to the point where another limitation exists. These conditions can be grouped into two categories: (1) inherited and (2) environmental. Most inherited limits and some environmental limits are difficult to influence. We can, however, influence the vegetative elements of habitat which limit food supply, protection, and reproduction. The basic conditions of wildlife habitat to be managed or protected are divided into seven categories; (1) grain and seed crops, (2) domestic grasses and legumes, (3) deciduous plants, (4) coniferous plants, (5) wild herbaceous plants, (6) wetland plants, and (7) edge. The categories are used to indicate percentage of cover type, the present condition of the cover, and may be used to predict conditions if cover type is improved or a change in land use occurs.

DETERMINING THE WILDLIFE RATING CRITERIA

Manage for a specific species. Determine the home range of the species, the minimum percentage of each cover type required, and the availability of woody cover. Determine the distance (in acres) that a species will travel throughout the year in utilizing the habitat (Soil Conservation Service, 1978a,b).

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[1] Paper presented at the Mitigation Sympo-.um, Fort Collins, Colorado, July 16-20, 1979.

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DETERMINING THE WILDLIFE RATING CRITERIA FOR VEGETATIVE CONDITIONS

1. From Table 1, circle the following:
    a. Daily range required by management species.
    b. Minimum percentage of required habitat present.
        Figures represent the minimum percentage of required habitat present before acreage calculations are performed.
    c. Minimum width of woody cover.
        Woody cover must meet minimum width requirements before it can be used in distance calculations.
    d. Determine travel distances.
        These figures represent the average distance that a species will travel throughout the year in utilizing the habitat.
2. Measure the edge of existing woodland and openland.
    Calculate the acreage for open (E-1) and woody (E-2) areas.
3. See appendix 1 for recording conditions.

DETERMINING QUALITY RATINGS FOR OPENLAND HABITAT

Openland habitat is evaluated for different wildlife species by determining the type and management condition of the vegetation present.

Habitat indexes for wildlife species hav been assigned to the various vegetative types and management conditions.

Habitat index value is determined for each openland vegetative type found within th home range of the species. Each value is the proportioned according to the percentage of that vegetative type in relation to the entir openland. The overall value for openland wil life is derived by totaling all the proportio ed values (Soil Conservation Service, 1978 a,

For example, a farm having 465 acres of openland habitat is evaluated for whitetail deer. The openland consists of 250 acres (54 of harvested combined corn; 180 acres (39%) of harvested combined soybeans; 26 acres (5%) of abandoned cropland which has voluntary perennials, with one or two species predomina ing and 9 acres (2%) of type 3 wetland. To rate for deer:

1. Read Table 2, item A, "Cropland." line 1.c, "Corn, regular till, good residue mgt." Read across the table to whitetail deer an find the assigned value of 0.90. Multiply 0.90 X 0.54 = 0.49.
2. Read Table 2, item A, line 2.b, "Soybeans, regular till, good residue mgt." Read acr to whitetail deer and find the figure 0.50. Multiply 0.50 X 0.39 = 0.20.
3. Read Table 2, item D, "Upland Herbaceous," line 7, "Voluntary perennials, with one or two species dominant." Read across to whi tail deer and find the figure 0.10. Multi 0.10 X 0.26 = 0.03.
4. Read Table 2, item F, line 2, "Inland non-

Table 1--Wildlife habitat rating criteria for vegetative condition.

	Whitetail Deer	Turkey	Cottontail Rabbit	Gray Squirrel	Bobwhite Quail	Gee
Daily Range (acres)	640	1,000	5	10	50	10
Minimum % habitat requirements for:						
1. Grain and seed crops	--	--	--	--	20	5
2. Domestic grass and legumes	20	10	60	--	--	--
or						
Wild herbaceous upland plants	20	10	60	--	10	--
3. Deciduous trees and shrubs	30	50	10	80	10	--
or						
Coniferous trees and shrubs	--	--	--	--	10	--
4. Open water	N/A	--	--	--	--	
Minimum Width of Woody Cover (ft)	300	300	15	100	15	--
Travel distances (feet)						
1. From edge to open area	500	150	100	150	150	Al
2. From edge to woody cover	All	All	100	All	150	--

NOTE: Woody or herbaceous hedgerows 100 ft or wider will be treated as woodland or herbaceous la respectively. Less than 5 ft in width will not be considered in calculations.
"All" indicates species will use entire area within home range.
Travel distances (feet) are selected for evaluation to reflect major use.

le 2. Quality rating criteria for openland habitat.

etative Type and Description	Assigned Values by Wildlife Species Quail	 Cottontail Rabbit	 Gray Squirrel	 Whitetail Deer	Geese	Turkey
Cropland						
Corn						
a. Silage	0.10	0.10	0.15	0.15	0.10	0.10
b. Conventional till, poor residue management	0.20	0.20	0.20	0.25	0.25	0.20
c. Conventional till, good residue management	0.75	0.30	0.90	0.90	0.90	0.90
d. Minimum or no-till	0.90	0.40	0.99	0.99	0.99	0.99
Soybeans						
a. Conventional till, poor residue management	0.15	0.15	0.10	0.10	0.10	0.10
b. Conventional till, poor residue management	0.75	0.30	0.20	0.50	0.70	0.60
c. Minimum or no-till	0.90	0.40	0.55	0.55	0.80	0.70
Small Grain						
a. Conventional till, poor residue management	0.25	0.15	0.01	0.30	0.30	0.30
b. Conventional till, good residue management	0.70	0.25	0.01	0.30	0.45	0.75
c. Cover Crop	0.25	0.60	0.05	0.50	0.70	0.50
Vegetables						
a. Conventional till, poor residue management	0.10	0.10	0.01	0.10	0.10	0.10
b. Conventional till, good residue management	0.20	0.20	0.05	0.15	0.25	0.25
c. Minimum or no-till	0.30	0.30	0.05	0.15	0.35	0.35
Nursery, Multi-Species						
< 25% herbaceous cover	0.35	0.55	0.30	0.50	0.05	0.20
> 25% herbaceous cover	0.55	0.99	0.36	0.80	0.01	0.50
Nursery or Orchard, Monospecies						
< 25% herbaceous cover	0.30	0.35	0.25	0.45	0.01	0.25
> 25% herbaceous cover	0.45	0.80	0.30	0.76	0.01	0.50
Upland Herbaceous						
Voluntary annuals, wide variety, 5% brush and vine canopy	0.85	0.60	0.10	0.40	0.15	0.80
Voluntary annuals, wide variety, 5-50% brush and vine canopy (>50% rated as wetland understory)	0.99	0.80	0.20	0.50	0.05	0.90
Voluntary annuals, 1 or 2 dominant species (i.e., crabgrass), <5% brush and vine canopy	0.10	0.10	0.05	0.10	0.50	0.70
Voluntary annuals, 1 or 2 dominant species, (i.e., crabgrass), 5-50% brush and vine canopy	0.15	0.15	0.10	0.20	0.10	0.80
Voluntary perennials, wide variety of beggar-ticks and green winter annuals, <5% brush and vine canopy	0.75	0.90	0.10	0.60	0.15	0.85
Voluntary perennials, wide variety of beggar-ticks and green winter annuals, 5-50% brush and vine canopy	0.85	0.95	0.30	0.75	0.05	0.95
Voluntary perennials, 1 or 2 dominant species (i.e., broome sedge) <5% brush and vine canopy	0.10	0.10	0.01	0.10	0.10	0.20
Voluntary perennials, 1 or 2 dominant species (i.e., broome sedge) 5-50% brush and vine canopy	0.20	0.20	0.10	0.20	0.01	0.30
Planted, 1 or 2 dominant species, <5% brush and vine canopy	0.10	0.10	0.01	0.30	0.30	0.25

Table 2. Quality rating criteria for openland habitat. (Continued)

Vegetative Type and Description	Assigned Values by Wildlife Species Quail	Cottontail Rabbit	Gray Squirrel	Whitetail Deer	Geese	Turke
D. Upland Herbaceous (Cont.)						
10. Planted, 1 or 2 dominant species, 5-50% brush and vine canopy	0.15	0.15	0.10	0.30	0.35	0.3
11. Planted, 1 or 2 dominant species, or being invaded by native species, <5% brush and vine canopy	0.70	0.70	0.25	0.70	0.30	0.6
12. Planted, wide variety of species, or being invaded by native species, 5-50% brush and vine canopy	0.70	0.70	0.25	0.70	0.30	0.6
13. Hayland mowed, not pastured	0.25	0.30	0.10	0.70	0.99	0.6
14. Sod farm	0.05	0.01	0.05	0.10	0.65	0.0
15. Mowed areas of native spec, not pastured	0.20	0.15	0.10	0.25	0.70	0.3
16. Well managed or lightly grazed pasture, veg. 4" high	0.20	0.40	0.30	0.60	0.90	0.5
17. Heavily grazed pasture, veg. 4" high	0.05	0.01	0.10	0.25	0.60	0.2
E. Brush and Vines[1]						
1. Brush and vines, 15-60% woody, < 25% conifers	0.95	0.99	0.80	0.99	0.05	0.6
2. Brush and vines, 15-60% woody, > 25% conifers	0.80	0.85	0.80	0.95	0.01	0.5
3. Brush and vines, 15-60% woody, < 25% conifers	0.80	0.80	0.99	0.95	0.01	0.6
4. Brush and vines, 60% woody, > 25% conifers	0.50	0.25	0.60	0.75	0.01	0.4
F. Wetland Herbaceous						
1. Coastal, permanent herbaceous	0.10	0.10	0.01	0.70	0.05	0.1
2. Inland nontidal, water present growing season	0.15	0.05	0.01	0.40	0.20	0.0
3. Inland nontidal, soil water-logged occasionally tilled	0.20	0.20	0.01	0.40	0.05	0.0
4. Inland tidal, low tide marsh	0.05	0.05	0.01	0.40	0.05	0.0
5. Inland tidal, high tide marsh	0.10	0.10	0.01	0.50	0.05	0.0

[1] 15% canopy of brush and vines, or seedling trees 2" d.b.h. included in item D above.

tidal, water present growing season." Read across to whitetail deer and find the figure 0.40. Multiply 0.40 X 0.02 = 0.08.

To find the value of all the openland habitat for whitetail deer, add the value ratings for each type of openland.

Corn = 0.49
Soybeans = 0.20
Upland Herbaceous = 0.03
Wetland = 0.08
TOTAL = 0.80

Adjective Rating: 0.00 - 0.25 = Poor
0.26 - 0.50 = Fair
0.51 - 0.75 = Good
0.76 - 1.00 = Excellent

5. See appendix 1 for recording conditions.

DETERMINING QUALITY RATINGS FOR WOODLAND HABITAT

Each type of woodland habitat is evaluate for different species of wildlife by analyzing and rating (1) dominant tree species compositio and (2) kind and amount of understory vegetatio

Both the dominant tree species compositio and understory composition have been assigned a value for each species of wildlife (Table 3).

Since dominant tree composition is more important than understory composition to some species of wildlife and vice versa, a weighted value has been assigned to each for various wildlife species. These values are shown in Table 3, item C.

The quality rating for a particular type of woodland and wildlife species is then derived by (1) multiplying the dominant tree weighted value and (2) adding the understory composition assigned value multiplied by the understory composition weighted value. Each

Table 3. Quality rating criteria for woodland habitat.

Woodland Species or Type and Description	Quail	Assigned Values by Wildlife Species Cottontail Rabbit	Gray Squirrel	Whitetail Deer	Turkey
A. Dominant Tree Composition					
1. 2-6" d.b.h. pines (>95% canopy cover)	0.05	0.99	0.01	0.15	0.01
2. 2-6" d.b.h. deciduous (>95% canopy cover)	0.05	0.75	0.20	0.65	0.20
3. 6"+ d.b.h. pines >95%, <5% desirable oaks, etc.	0.15	0.01	0.05	0.01	0.05
4. 6"+ d.b.h. pines 50-95%, 5-50% desirable oaks, etc.	0.65	0.10	0.35	0.25	0.40
5. 6"+ d.b.h. pines 5-50%, 50-95% desirable oaks, etc.	0.75	0.15	0.65	0.45	0.50
6. 6"+ d.b.h. pines and maple-gum	0.20	0.15	0.25	0.20	0.10
7. 6"+ d.b.h. oaks and other desirable species	0.80	0.20	0.99	0.99	0.99
8. 6"+ d.b.h. maple-gum perdominant	0.10	0.10	0.30	0.40	0.10
9. 6"+ d.b.h. bottomland, mixed species	0.90	0.80	0.75	0.95	0.70
B. Understory Composition					
1. Sparse - no woody species	0.10	0.01	0.01	0.01	0.15
2. Sparse - a few shrubs	0.15	0.10	0.10	0.10	0.40
3. Medium - conifers & other evergreens >50%	0.30	0.35	0.15	0.15	0.25
4. Medium - conifers & other evergreens <50%	0.85	0.50	0.60	0.40	0.45
5. Medium - evergreen 50% (<5% pine)	0.25	0.40	0.30	0.50	0.30
6. Medium - evergreen 5-50% (<5% pine)	0.80	0.55	0.45	0.50	0.45
7. Medium - deciduous, 1 or 2 species predominate	0.20	0.55	0.55	0.30	0.50
8. Medium - deciduous, 3 or more species predominant	0.90	0.95	0.99	0.75	0.99
9. Medium - mainly slash in cut over area	0.99	0.90	0.01	0.45	0.15
10. Heavy - conifers (other evergreens >50%)	0.30	0.55	0.05	0.40	0.01
11. Heavy - conifers (other evergreens <50%)	0.70	0.70	0.60	0.60	0.15
12. Heavy - evergreens >50% (<5% pine)	0.25	0.65	0.15	0.55	0.10
13. Heavy - evergreens <50% (<5% pine)	0.70	0.80	0.50	0.75	0.15
14. Heavy - deciduous, 1 or 2 species predominant	0.25	0.60	0.55	0.55	0.15
15. Heavy - deciduous, 3 or more species predominant	0.95	0.99	0.95	0.99	0.60
C. Weighted Values					
1. Tree composition importance	0.10	0.10	0.90	0.40	0.55
2. Understory importance	0.90	0.90	0.10	0.60	0.50

woodland type is rated and proportioned according to the present total woodland area that particular type composes (Soil Conservation Service, 1978a,b).

For example, a farm has 340 acres of woodland. Twenty acres (6%) have a dominant tree species of 2-to 6-inch d.b.h. pines with >95% canopy cover and understory composition described as sparse, no woody species. Forty-three (10%) have a dominant tree composition (50-95%) of >6-inch d.b.h. pines, 50% desirable oaks, etc., with an understory composition described as sparse, few shrubs. Mixed bottomland species (>6-inch d.b.h.) with a medium understory of two predominate species of deciduous shrubs occupy 168 acres (39%), while 199 acres (45%) have a dominant tree composition of >6-inch d.b.h. oaks and other desirable species and an understory composition of medium density deciduous shrubs with three or more species predominating.

To calculate the woodland habitat rating for whitetail deer:

1. Woodland type 2-to 6-inch d.b.h. pine
   a. Dominant tree composition
      1) Assigned value. Read Table 3, item A, line 1, "2-to 6-inch d.b.h. pines (>95% canopy cover)." Read across to whitetail deer and find the assigned value of 0.15.
      2) Weighted value. Read Table 3, item C, line 1, "Tree composition importance." Read across to whitetail deer and find the weighted value of 0.40.
      3) Value of dominant tree composition. Multiply the assigned value by the weighted value:

0.15 X 0.40 = 0.06.

b. Understory composition value:
   1) Assigned value. Read Table 3, item B, line 1, "Sparse no woody species." Read across to whitetail deer and find the assigned value of 0.01.
   2) Weighted value. Read Table 3, item C, line 2, "Understory importance." Read across to whitetail deer and find the assigned value of 0.60.
   3) Value of understory composition. Multiply the assigned value by the weighted value:

      0.01 X 0.60 = 0.06.

c. Value of the woodland type equals dominant tree composition value plus the understory composition value:

   0.06 + 0.06 = 0.12.

d. Prorated value of the 2-to 6-inch d.b.h. pine equals the value of the woodland type multiplied by percentage of woodland type:

   0.12 X 0.06 = 0.01.

2. Woodland type >6-inch d.b.h. pines 50-95%, 50% desirable oaks, etc.; understory composition sparse with few shrubs.
   a. Dominant tree composition value:
      1) Assigned value. Read Table 3, item A, line 4, ">6-inch pines 50-95%." Read across to whitetail deer and find the assigned value of 0.25.
      2) Weighted value. Table 3, item C, line 1, "Tree composition importance." Read across to whitetail deer and find the weighted value of 0.40.
      3) Dominant tree composition value equals assigned value multiplied by weighted value:

         0.25 X 0.40 = 0.10.

   b. Understory composition value:
      1) Assigned value. Table 3, item B, line 2, "Sparse, few shrubs." Read across to whitetail deer and find the assigned value 0.10.
      2) Weighted value. Table 3, item C, line 2, "Understory importance." Read across to whitetail deer and find the weighted value of 0.60.
      3) Understory composition value equals assigned value multiplied by weighted value:

         0.10 X 0.60 = 0.06.

   c. Woodland type value equals dominant tree composition value plus understory composition value:

      0.10 + 0.06 = 0.16.

   d. Prorated woodland type value equals woodland type value multiplied by the percentage of woodland type:

      0.16 X 0.10 = 0.02.

3. Woodland type >6-inch d.b.h. bottomland, mixed species with an understory composition of medium density deciduous shrubs, two species dominating.
   a. Dominant tree composition:
      1) Assigned value. Read Table 3, item A, line 9, ">6-inch d.b.h. bottomland, mixed species." Read across to whitetail deer and find the assigned value of 0.95.
      2) Weighted value. Read Table 3, item C, line 1, "Tree composition importance." Read across to whitetail deer and find the weighted value of 0.40.
      3) Dominant tree composition value equals assigned value multiplied by the weighted value:

         0.95 X 0.40 = 0.38.

   b. Understory composition value:
      1) Assigned value. Read Table 3, item B, line 7, "Medium-deciduous, one or two species predominating." Read across to whitetail deer and find the assigned value of 0.30.
      2) Weighted value. Read Table 3, item C, line 2, "Understory importance." Read across to whitetail deer and find the weighted value of 0.60.
      3) Understory composition value equals the assigned value multiplied by the weighted value:

         0.30 X 0.60 = 0.18.

   c. Woodland type value equals dominant tree composition value plus the understory composition value:

      0.38 + 0.18 = 0.56.

   d. Prorated value of woodland type equals woodland value multiplied by the percentage of woodland type:

      0.56 X 0.39 = 0.22.

4. Woodland type >6-inch d.b.h. oaks and other desirable species with an understory of medium density deciduous shrubs with three or more species predominating.
   a. Dominant tree composition value:
      1) Assigned value. Read Table 3, item A, line 7, ">6-inch d.b.h. oaks and other desirable species." Read across to whitetail deer and find the assigned value of 0.99.
      2) Weighted value. Read Table 3, item C, line 1, "Tree composition importance." Read across to whitetail deer and find the weighted value of 0.40.
      3) Dominant tree composition value equals assigned value multiplied by the weighted value:

         0.99 X 0.40 = 0.40

   b. Understory composition value:
      1) Assigned value. Read Table 3, item B, line 8, "Medium-deciduous, three or more species predominating." Read across to whitetail deer and find the assigned value of 0.75.

2) Weighted value. Read Table 3, item C, line 2, "Understory importance." Read across to whitetail deer and find the weighted value of 0.60.

3) Understory composition value equals the assigned value multiplied by the weighted value:

$$0.75 \times 0.60 = 0.45.$$

c. Woodland type value. Dominant tree composition value plus the understory composition value equals:

$$0.40 + 0.45 = 0.85.$$

d. Prorated value of the woodland type equals the woodland type value multiplied by the percentage of woodland type:

$$0.85 \times 0.45 = 0.40.$$

To find the value of all the woodland habitat to whitetail deer, add the prorated values of each woodland type:

2-to 6-inch d.b.h. pine	0.01
>6-inch d.b.h. pine	0.02
>6-inch d.b.h. bottomland	0.22
>6-inch d.b.h. oaks	0.40
Total woodland habitat value	0.65

Adjective Rating: 0 - 0.25 = Poor
0.26 - 0.50 = Fair
0.51 - 0.75 = Good
0.76 - 1.00 = Excellent

e. Acreage calculations of principal use open and woody areas:

$$\frac{\text{Length of Edge (ft) distance from Woody cover (ft)} =}{43{,}560 \text{ ft/ac}}$$

$$\frac{\text{Length of Edge (ft) X distance into Woody Cover (ft)} =}{43{,}560 \text{ ft/ac}}$$

f. Remarks.
To be meaningful, each rating should be at least 25% of the combined habitat quality rating.

g. See appendix 2 for recording conditions.

CONCLUSION

The numerical rating may be used as is or converted to an adjective rating. Biologists with different backgrounds and experience may not agree with the details of the rating system. However, a numerical rating system allows flexibility in improving or replacing habitat on a one-to-one basis.

If a habitat for a species is rated at 0.57, for example, by reviewing the inventory and point values the lowest rating element may be improved thus raising the overall rating.

Replacement is assumed to be on an ac/ac value. However, since acreage is considered in the evaluation procedure a higher value can be used to offset a lower acreage and vice versa. For example, a habitat of 100 acres having a value of 0.30 could be replaced with a 50-acre habitat having a rating value of 0.60.

This system could be modified to apply to various habitats. Future conditions should be evaluated after various changes. This system can solve many of the problems of existing methods if accepted by wildlife biologists and other concerned agencies.

(SEE APPENDIX 1, 2 & 3 attached)

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Appendix 1: Field Work Sheet for Wildlife Evaluation Computation Sheet

John Doe (Cooperator)	(Evaluator)
805 (Total Farm Acreage)	(District)
Whitetail Deer (Species Evaluated)	(Date)

OPENLAND HABITAT

465 Total Acres | 58 % of Total Farmland

Vegetative Type and Description (1)	Acres (2)	% of Openland Acreage (3)	Assigned Value (4)	Column 3 X 4 (5)
A. Cropland				
Corn-Conv. Tillage	250	54	0.90	0.49
Soybeans-Conv. Tillage	180	39	0.50	0.20
B. Nursery, Multi-Species	N/A	N/A	N/A	N/A
C. Nursery or Orchard, Mono-Species	N/A	N/A	N/A	N/A
D. Upland Herbaceous	26	5	0.10	0.005
E. Brush and Vines	N/A	N/A	N/A	N/A
F. Wetland Herbaceous	9	2	0.40	.008

Total Value = 0.703

Adjective Rating System	
0.00 - 0.25	Poor
0.26 - 0.50	Fair
0.51 - 0.75	Good
0.76 - 1.00	Excellent

Adjective Rating = Good

Appendix 2: Woodland Habitat

340 (Total Acres) | 42 (% of Total Farmland)

(1) Woodland Type Description	(2) Acres	(3) % of Total Woodland	(4) Dominant Tree Composition Value	(5) Weighted Value	(6) Column 4 X 5	(7) Understory Composition Value	(8) Weighted Value	(9) Column 7 X 8	(10) Value of Woodland Type Column 6 + 9	(11) Prorated Value Woodland Type Column 3 X 10
2-6" d.b.h. Pine--95% Canopy Understory Sparse--No woody species.	20	6	0.15	0.40	0.06	0.01	0.60	0.06	0.12	0.01
>6" d.b.h. Pine--50-95%, 50% desirable oaks, etc. Understory sparse with few shrubs.	43	13	0.25	0.40	0.10	0.10	0.60	0.60	0.16	0.02
Mixed bottomland species >6", d.b.h. medium understory of deciduous shrubs, 2 species dominating.	168	49	0.95	0.40	0.38	0.30	0.60	0.18	0.56	0.27
>6" d.b.h. oaks and other desirable species. Understory--medium density deciduous shrubs with 3 or more species dominating.	109	32	0.99	0.40	0.40	0.75	0.60	0.45	0.85	0.27

Total Value = 0.57 Adjective Rating = Good

Appendix 3: Combined Habitat Quality Rating.

1. Openland habitat quality rating equals percentage of openland in farm multiplied by value rating.
2. Woodland habitat quality rating equals percentage of woodland in farm multiplied by value rating.
3. Combined habitat quality rating equals openland habitat quality rating plus woodland habitat quality rating. For example,

if

Openland = 465 acres (58%)
Woodland = 340 acres (42%)
Farm total = 805 acres (100%)

then

Openland habitat quality rating = 0.58 X 0.70 = 0.41
Woodland habitat quality rating = 0.42 X 0.57 = 0.24
Combined habitat quality rating = 0.65

Adjective ratings:

0-0.25 = Poor
0.26-0.50 = Fair
0.51-0.75 = Good
0.76-1.00 = Excellent

An Evaluation of Alternatives for Improving the Mitigation Process[1]

Ann G. Rappoport[2]

Abstract.--Evaluated mitigation by questionnaire and congressional internship. Many differences ($P < 0.1$) between Bureau of Reclamation, federal and state wildlife agency, and conservation group respondents. Wildlife agencies must document funding and staffing needs. Needed definitions and requirement for habitat evaluations are provided by proposed regulations. An interagency committee and project funding dependent on FWCA compliance could further improve mitigation.

With technological advances of the twentieth century, Americans have come to consider specialized appliances and limitless water a standard part of life. Yet the natural resource developments necessary to maintain this lifestyle come at the expense of our fish and wildlife resources.

The primary vehicle for minimizing modification and loss of fish and wildlife habitats from water developments has been the Fish and Wildlife Coordination Act (FWCA). But equal consideration of fish and wildlife conservation with those developments has not been the rule prescribed by the last amendment of the Coordination Act over two decades ago (16 U.S.C. 661 et seq.). Barely 56,000 acres have been acquired to mitigate wildlife losses from 189 Bureau of Reclamation and Corps of Engineer's projects (U.S. House of Representatives 1978:648-699). Those projects inundated nearly 2 million acres of land.

Complicated by changing laws and the lengthy nature of project development, the mitigation of wildlife losses required by the FWCA is a complex process. The purpose of this study was to develop recommendations for improving fish and wildlife mitigations. Two approaches were undertaken to accomplish this purpose: first, a survey of knowledgeable individuals, and second, a legislative internship. The focus of this paper is on the mitigation process and terrestrial wildlife losses associated with Bureau of Reclamation water projects.

The paper is organized into two parts. An overview of each approach to the evaluation is given in the first part. The overview includes questionnaire results and political activities pertinent to improving the mitigation process. In the second part, major issues in fish and wildlife mitigations are discussed and recommendations are made regarding each issue. This research was made possible through an NSF energy-related graduate traineeship; a Shell Aid in Natural Resources Policy; the Office of Biological Services, U.S. Fish and Wildlife Service, contract number 14-16-0008-2016; and the office of Congressman James L. Oberstar.

The author would like to acknowledge Dr. Julius G. Nagy, without whose support and encouragement the study would have been impossible. The author is also indebted to Judy A. Voigt for her tireless assistance and own work on mitigation.

OVERVIEW OF QUESTIONNAIRE AND INTERNSHIP

The first approach to the study involved a questionnaire on the mitigation process. This questionnaire was sent to individuals involved with water developments and fish and wildlife mitigations. The return was 70 percent or 219 questionnaires.

In completing the questionnaire, respondents were asked to choose and rank--as best, second best, and third best--alternatives for ensuring effective implementation of the mitigation process. Because interagency agreement has often been lacking in mitigation efforts, responses were compared between the four main groups into which respondents were categorized--the Bureau of Reclamation (BR), U.S. Fish and Wildlife Service (FWS), state fish and wildlife agencies (STWL), and conservation organizations (CNSERV).

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[1] Paper presented at the National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Fort Collins, Colorado, July 16-20, 1979.

[2] Biological Technician, U.S. Fish and Wildlife Service, Anchorage, Alaska.

There were frequently significant differences ($P < 0.1$) between respondent groups with respect to the questionnaire options each ranked best. Preferred options tended to promote interests of the group in question. For wildlife and conservation groups, this meant a greater voice and funds for various stages of the mitigation process. For the construction group, this meant fewer responsibilities. Options ranked second best, however, were often a logical compromise with each group more willing to accept the input and responsibilities of other groups.

Two additional trends were evident in responses to the questionnaire:

(1) Options ranked best by the largest proportions of FWS, STWL, and CNSERV were frequently identical, but of less importance to BR.

(2) BR was the group most interested in maintaining the status quo.

Most responses to the questionnaire, especially those from wildlife agencies and conservation organizations, supported many provisions of Congressman James L. Oberstar's bill to amend the FWCA, H.R. 8161. The second approach, then, was an internship with Congressman Oberstar. This internship was a unique opportunity to examine the feasibility of preliminary study recommendations within the constraints of Administrative policies, agency budgets and public concerns. Concurrent with the internship, two political activities of immediate importance to the study were: (1) announcement of a National Water Policy (U.S. House of Representatives 1978:342-370); and (2) House Subcommittee on Fisheries and Wildlife Conservation and the Environment oversight hearings into administration of the Fish and Wildlife Coordination Act (U.S. House of Representatives 1978).

IMPROVING THE MITIGATION PROCESS

Amending the FWCA initially appeared the optimum alternative for improving the mitigation process (Rappoport et al. 1977). However, the controversies surrounding such amendment were confirmed by different responses to the questionnaire ($P < 0.02$). While wildlife and conservation interests believed amendment of the FWCA was necessary to improve wildlife mitigations, respondents with the Bureau of Reclamation thought current laws and policies were adequate.

Amendment of the Coordination Act proved politically impossible in the 95th Congress. Yet the questionnaire option which was a reasonable compromise among wildlife, construction, and conservation interests was realized. This compromise was to amend agency policy and procedural guidelines. As effected by the President's Water Policy Directives of 1978, amendment of agency guidelines will come through: (1) Interior and Commerce promulgation of rules and regulations for implementing the FWCA; (2) construction agency demonstration of compliance with the FWCA in annual budget submissions to the Office of Management and Budget; (3) inclusion of all environmental mitigation funds in appropriation requests for project construction; and (4) concurrent and proportional expenditures for mitigation and construction throughout project life (U.S. House of Representatives 1978:342-370). After the 1978 oversight hearings on the FWCA, the general concensus was to let Interior promulgate regulations before further attempts are made to amend the FWCA (U.S. House of Representatives 1978:275-283, 303-320).

PROBLEMS AND REMEDIES--EIGHT ISSUES

Recommendations for improving the mitigation process are made in terms of eight issues. Each issue is discussed relative to questionnaire data and the recently proposed FWCA regulations (U.S. Department of Interior et al. 1979).

Defining Mitigation

It is difficult to obtain interagency agreement and implement fish and wildlife mitigations when each party interprets the subject differently. This difficulty was demonstrated by the significant differences between the four respondent groups with regard to the mitigation definitions each ranked best ($P < 0.001$) and second best ($P < 0.06$). The division within each group and substantial number of respondents providing definitions other than those given indicated lack of a consensus on this issue.

The Coordination Act regulations consistently apply to all agencies. As recently proposed, they should effectively improve this aspect of the mitigation process by (1) setting out a clear and simple definition of mitigation; (2) delineating boundaries between mitigation, compensation, replacement, and enhancement; and (3) providing guidelines for the consultation and consideration requirements of the FWCA (50 CFR 410.3).

Evaluative Criteria

Past efforts to mitigate fish and wildlife losses have often involved unreliable and inconsistent evaluations of affected ecosystems (Rappoport et al. 1977). Management practices accepted on the basis of these evaluations have been ineffective in decreasing wildife losses. Construction and wildlife agencies have not yet agreed on a uniform system for arriving at mitigation recommendations or the criteria for accepting, rejecting, or modifying those recommendations.

Questionnaire respondents preferred basing pre-development evaluations and mitigation justifications on habitat rather than the traditional monetary accounting of user-days. Wildlife productivity and monetary considerations were ranked as useful supplementary factors. Although the response to questions on evaluative criteria did not differ ($P < 0.1$) between respondent groups, respondents with BR were less interested in the specific U.S. Fish and Wildlife Service Habitat Evaluation Procedure (HEP) than in a general "habitat-based evaluation."

Construction agency reluctance to adopt the Service's HEP was apparent during the oversight hearings on the FWCA. Bureau of Reclamation Commissioner R. Keith Higginson testified to the problems of handling HEP-based recommendations in traditional terms (U.S. House of Representatives 1978:338-380). Yet there is no legislative mandate for evaluating wildlife losses or justifying mitigation recommendations by the traditional assignment of dollar values to hunting and fishing "user-days" gained or lost with project development. The Senate report on the 1958 Coordination Act amendment (S. 1981) specifies that mitigation measures "would not have to be justified under the usual benefit-cost type of analysis;" dollars would not be used to evaluate wildlife losses.

The proposed FWCA regulations complement responses to the questionnaire. They require wildlife agencies to use techniques "directed at quantifying and qualifying potential effects upon wildlife, their habitat and related values" in evaluating project-related impacts and mitigation alternatives (50 CFR 410.23(c)(2) and (3)). Construction agencies are to decide what mitigation recommendations are justifiable by "evaluation techniques based upon wildlife habitat values" (50 CFR 410.24(b)(1)). Monetary values may not be used to jusitify mitigative alternatives.

Early Planning

If project plans are to best serve both wildlife and project goals, water developments must involve wildlife agencies and the public from the earliest stages of project conception. Both federal and state wildlife agency respondents to the questionnaire believed increasing funds and personnel were most essential to timely and complete pre-development evaluations. In data provided for the Coordination Act hearings, the USFWS claimed to have less than half the staff needed to fulfill their responsibilities under the FWCA (U.S. House of Representatives 1978:75-78, 504-519).

Individuals associated with the Bureau of Reclamation and conservation organizations have been less involved than have the wildlife agencies in actually completing pre-development evaluations. Respondents with these groups were most concerned with establishing an interagency liaison committee to aid early project and mitigation planning. In addition to the wildlife and construction agencies, this committee would include local and conservation group representatives.

Interagency agreement on mitigation plans is another factor crucial in early planning. The difficulty of obtaining such agreement was evident in respondent support for the interests of the group with whom each was affiliated. Thus Bureau of Reclamation respondents were most satisfied with the status quo whereby only mitigation recommendations acceptable to the construction agency are included in project plans submitted to Congress. Wildlife and conservation groups, however, wanted to require interagency agreement on mitigation prior to requests for either congressional authorization or funding.

Having an interagency committee work out differences between wildlife agency recommendations and construction agency desires was a possible compromise to different respondent group interests. That option was primarily chosen as a second best response.

Early Planning Under the Proposed Rules

The proposed rules include no provisions for an interagency committee. Yet such a committee could be an effective forum for coordinating project development with wildlife considerations. An interagency committee could ensure the early public notification and participation advocated by conservation and state wildlife witnesses at the oversight hearings (U.S. House of Representatives 1978: 124-132, 145-159, 193-206). The committee could be instrumental in organizing well-advertised, informative public hearings on mitigation disagreements.

The regulations enhance opportunities for continued wildlife agency input and early planning by requiring wildlife and construction agencies to: (1) establish planning goals; (2) convene scoping meetings for agreeing upon study timetables and required coordination; and (3) be jointly responsible for early exchanges of information. In addition to specific mitigation measures, goals and timetables were the two factors all respondent groups considered most important to include in FWCA reports.

Assurance that mitigation becomes a part of project plans could be provided by one further practice. This would be to prohibit requests to Congress for project authorizations or appropriations until either (1) mitigative features are incorporated into project plans, or (2) construction agencies account for rejected wildlife recommendations by the procedure established in the regulations.

To date, wildlife agency input to congressional authorization and appropriation processes has been virtually nonexistent. Wildlife recommendations remain buried in bulky project documentation. Several questionnaire respondents noted the need to better inform Congress of the potentials for mitigating fish and wildlife losses. Construction agency and congressional interests have supported promoting congressional attention to the mitigation plan by having wildlife agencies appear with construction agencies before authorization and appropriation committees (U.S. House of Representatives 1978:338-380).

The proposed regulations provide the opportunity, but not requirement, for wildlife agencies to participate in these legislative proceedings (50 CFR 410.31). Wildlife agencies must take full advantage of this opportunity to ensure equal consideration of fish and wildlife in water project development.

Implementing the Mitigation Plan

Beyond planning, timing continued to be a prime concern to both questionnaire respondents and witnesses at the FWCA oversight hearings. There was no difference ($P > 0.1$) between respondent groups with regard to measures preferred for facilitating implementation. Respondents wanted to guarantee both the timely allocation of mitigation funds and timely acquisition of wildlife lands. While neither of these practices was required at the time of the questionnaire, both have essentially been enacted by the President's Water Policy Directives for including and expending mitigation funds concurrently with project construction appropriations (U.S. House of Representatives 1978:342-370).

Another practice supported by questionnaire respondents was to require annual reports on the progress of mitigation, reports analogous to the FWCA compliance reports now required in annual budget submissions (U.S. House of Representatives 1978:342-370). But while the respondents group BR preferred submitting annual reports to the Secretary of the Interior, FWS and STWL wanted them sent to Congress with funding requests. CNSERV believed the reports should go to an interagency committee for review and recommendations. The President's Water Policy resolved this difference by directing submission of compliance reports to the Office of Management and Budget (OMB). An agency which reports directly to the President, OMB is neutral to respondent group concerns. "OMB" was not a questionnaire option.

Operation, Maintenance, and Follow-up

BR respondents were more interested than other respondents in leaving operation and maintenance ($P < 0.03$), as well as follow-up ($P < 0.05$), as optional parts of the mitigation process. The wildlife and conservation groups advocated tying appropriations for operation, maintenance, and follow-up to appropriations for project operations. All respondent groups believed there should be periodic reports on the effectiveness of implemented mitigation plans.

The proposed regulations clarify that funding for operating and maintaining mitigation is to be budgeted by the construction agency. Although the regulations provide the opportunity and means for post-authorization studies and associated funding, they do not mandate it (50 CFR 410.33). With existing staff and funds, wildlife agencies are not capable of follow-up on every project. However, the FWCA compliance reports should at least indicate whether planned mitigations have taken place.

FWCA compliance reports should help improve fish and wildlife mitigations if they are more than a bureaucratic check-off. It would be consistent with the intent of the President's directives for the proposed rules to make provision of project funds depend upon documented compliance with the FWCA.

Funding

The respondent groups significantly ($P < 0.01$) differed with respect to the sources of mitigation funding each ranked best. Again, choices reflected a group's self-interest.

In general, wildife and conservation groups wanted project funds allocated to the Fish and

Wildlife Service and transferred to the local state wildlife agency for all stages of mitigation. At present, the FWCA only provides fund transfers to the Service for pre-development investigations. Unless further funding is aggressively pursued by wildlife agencies, construction agencies typically refuse to fund operation and maintenance or follow-up.

Bureau respondents, however, supported current arrangements whereby the construction and wildlife agencies fund pre-development studies; the construction agency funds implementation; the construction or state wildlife agency funds operation and maintenance; the Fish and Wildlife Service funds post-development evaluations; and Congress decides who should fund further mitigation.

Similar satisfaction with the status quo was attested to by the Bureau, Corps of Engineers, and Soil Conservation Service during the 1978 Coordination Act hearings (U.S. House of Reprensentatives 1978:321-384). None of these agencies has been affected, as have the wildlife agencies, by lack of staff and funds or by impacts to resources under their jurisdiction.

Federal and state agencies must be furnished adequate staff and funds for all phases of the mitigation process. With public backing, an agressive campaign by the wildlife agencies can help persuade Congress to increase wildlife agency base funding, fund transfers from the project to the wildlife agencies, and personnel ceilings. Wildlife agencies may find it painful to document their current capabilities in relation to their needs. But unless those agencies actively work to improve both their public and congressional support, wildlife will continue to lose--both in habitat quality and quantity.

Retrofit

The President's recent water policy announcement, in conjunction with changing agency attitudes, should result in appropriate fish and wildlife mitigations on future water developments. Yet of 1900 federal water projects in various stages of planning and construction, nearly 1300 have already been authorized and countless others completed, many with incomplete or no fish and wildlife plans (Office of the White House Press Secretary 1978).

Questionnaire respondents were asked what steps should be taken when initial mitigation goals are not achieved. The response was significantly different between respondent groups ($P < 0.01$). BR respondents were least interested in restricting project development when mitigation does not proceed as planned and most willing to keep further mitigation attempts independent of the project.

The regulations furnish a mechanism for authorizing review and retrofit of mitigation to existing projects (50 CFR 410.12(b) and (c)) However, the regulations leave initiation of the review to Secretarial discretion and completion of the review to the construction agencies. The regulations should be strenghtened to require brief reviews of all projects which have come under the FWCA. There must be in-depth reviews where fish and wildlife mitigations have been less than satisfactory and there is the potential for further action. These reviews must include input from federal and state wildlife agencies. Data gathered in conjunction with last year's oversight hearings on the FWCA offer a first level assessment of the need and opportunity for mitigation on already authorized projects (U.S. House of Representatives 1978:648-699).

Outlook for the Future

Based upon responses to the questionnaire, testimony presented at the oversight hearings, and numerous consultations with involved individuals from all interests, the outlook for improving the mitigation process is encouraging. But this outlook will become reality only if the FWCA regulations incorporat the additional provisions outlined here and water project developments fully adhere to those regulations.

Final work in improving the mitigation process, however, must come through Congress. Once the President's directives have been fully implemented it would be well to amend the Coordination Act, thereby legislating the President's Water Policy. Amendment could accomodate factors such as funding, which the regulations and other directives cannot fully address. Meanwhile, wildlife agencies must aggressively pursue their missions, construction agencies must fully involve wildlife agencies and the public throughout water resource planning and development, and Congress must be constrained from pushing "pork barrel" projects. Only then will society's needs for water and energy be satisfied with the least harm to fish and wildlife resources.

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Adequacy and Accuracy of Fish and Wildlife Impact Assessments at Corps of Engineers Projects [1]

Norville S. Prosser[2], Robert G. Martin[3], and Richard H. Stroud[4]

Abstract.--This interim review documents the paucity of quantitative data available for evaluation of water resource development impacts and highlights the inadequacy of past fish and wildlife planning at Corps of Engineers reservoir projects based upon the screening of data availability at 410 projects and case history studies of 10 projects.

INTRODUCTION

Federal programs designed to accomplish the development of water resources have wrought enormous changes to fish and wildlife communities and associated societal use patterns. Such obvious alterations of physical systems have provoked sweeping generalizations regarding the impacts of water development projects on natural resources. There are those who are so prejudiced against reservoirs that they can discern only environmental and social insult from water development projects. Equally, there are those who are so prejudiced in favor of water development that they will admit to no adversities associated with such construction programs.

This dichotomous rhetoric with respect to perceived influences of lake construction on fish and wildlife values has developed largely without benefit of objective study. The record enjoys few in-depth studies of mitigation efficacy or systematic monitoring of actual fish and wildlife-related impacts at water development projects. Conclusive evidence of the impacts of water development projects on fish and wildlife resources can only be realized through comprehensive on-site fish and wildlife resource studies at existing projects and comparison of these data against accurate measurements of these same resources made prior to construction.

This informational deficiency has become increasingly recognized in recent years. A 1970 review of fish and wildlife planning at water development projects undertaken by the Fish and Wildlife Service, state fish and wildlife agencies, and many national conservation organizations, produced a list of 169 recommended corrective actions including the following (White 1971):

> "Study projects under construction and completed to determine if recommended fish and wildlife features are being provided, to evaluate results of previous recommendations, and to provide basic data for future evaluations and recommendations."

The effectiveness of past fish and wildlife planning at water projects has also been a matter of growing concern among the construction agencies. In 1974 the U.S. Army Corps of Engineers awarded a contract to the Sport Fishing Institute to evaluate the efficacy of the predictive aspects of the fish and wildlife planning reports for Corps reservoir projects and to develop specific information upon which to improve the reliability of these predictions. This paper summarizes the interim results of investigations of the adequacy and predictive value of fish and wildlife planning reports at U.S. Army Corps of Engineers reservoir projects.

Some Perspective

A review of habitat availability for terrestrial wildlife and fish may be helpful for perspective. It has been estimated that undeveloped lands supporting terrestrial wildlife comprise about 75 percent of the total land area of the contiguous 48 states, or some 1.41 billion acres. Approximately 87 percent (1.24 billion acres) of these undeveloped lands are hunted (Shields and Swanson 1969). Stroud (1977) estimated the freshwater resources in the contiguous U.S. totalled 33,331,000 acres (excluding 38,700,000 acres within the Great Lakes). Practically all of these waters are fished.

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According to nationwide surveys conducted by the U.S. Fish and Wildlife Service's National Reservoir Research Program, reservoirs of 500 surface acres or more totalled approximately 9,774,000 acres by January 1, 1976 (R. Jenkins, personal communication). Assuming a ten to one relationship between impounded waters to pre-impoundment stream acreage, reservoir construction has netted an additional 8,885,446 acres of aquatic habitat, which constitutes approximately 27 percent of the aquatic habitat (exclusive of the Great Lakes) in the 48 contiguous states. Conversely, the corresponding loss of terrestrial habitat from reservoir construction constituted 0.6 percent of current estimates of undeveloped lands capable of supporting wildlife.

During the period 1970 to 1976, the loss of terrestrial wildlife habitat from impoundment has averaged approximately 140,910 acres (an annual loss of 0.01 percent). Average annual losses of terrestrial wildlife habitat from urban expansion during a comparable period 1969 to 1974 (43,200 acres per year) and highway construction (143,000 acres), totalled 186,200 acres per year (Fry 1969, 1974).

AVAILABILITY OF IMPACT DOCUMENTATION

The first objective of the investigation entailed the compilation, analysis and evaluation of existing sources of fish and wildlife-related pre-impoundment and post-impoundment information at selected Corps projects. To accommodate this design, in lieu of acquiring the needed data by original field investigation, it was necessary to locate an adequate number of Corps projects for which there were available quantitative, pre-impoundment resource and utilization inventories as well as predicted post-impoundment occurrences within the same categories. Also, it was essential that post-impoundment data be available describing the actual fish and wildlife-related conditions on project and project-related lands and waters.

Screening of Corps projects also considered reservoir type (flood control, hydroelectric, etc.) as well as geographical location. The screening objectives were to select documented projects of all basic types and projects representative of the widest possible range of geographical locations. Preliminary screening of the 410 projects extant in 1974 also considered age of the project. It did not become mandatory for Federal construction agencies to request comments and recommendations from Federal and State conservation agencies regarding project impact on fish and wildlife resources until the Fish and Wildlife Coordination Act was passed by Congress in 1946. The average delay between issuance of fish and wildlife predictive report and reservoir completion was determined to be six years. Therefore, the 138 projects completed prior to 1953 were eliminated from further consideration.

Projects which result in little or no new water acreage affect fish and wildlife resources to a much smaller degree than projects which result in significantly increased flooded acreages. Considering this relationship, 124 projects with no permanent impoundments, or with minimal new water area, were eliminated from further consideration. The number of projects completed since 1953, which resulted in significant habitat modification totalled 148. However, 28 of these projects were considered marginal because of adverse interracting factors of age and size in comparison with other projects in or near the same Corps of Engineers District. These 28 projects were not subjected to further investigation.

Second-level screening for the remaining 120 largest, most recently completed, projects considered the extent to which each had received pre-impoundment evaluation by the Federal and State game and fish conservation agencies. Locating and acquiring these preconstruction Fish and Wildlife Service planning reports for 120 projects proved to be a difficult task.

The accumulated reports, documents, and related correspondence for each reservoir were reviewed to determine the extent to which the pre-construction fish and wildlife resources were described and to ascertain the quality and comprehensiveness of the post-impoundment predictions. Project personnel considered the pre-impoundment planning reports as being adequate to permit post-impoundment comparative studies for 78 of the 120 project files reviewed. The elimination of 42 projects (35 percent) due to the cursory nature of the planning documents was in itself a significant reflection of the inadequate treatment given to fish and wildlife matters at water development projects in the past.

To ascertain the extent of documentation for actual site-specific impacts to fish and wildlife resources for the remaining 78 projects, the appropriate state fish and wildlife agency was asked by questionnaires to identify and describe the extent of post-construction fish and wildlife survey data available for each project. It quickly became evident that very few of these projects had received post-construction follow-up evaluation for both fish and wildlife resources. No follow-up data of any consequence were available for either fishery or wildlife resources at 32 projects (41 percent). Post-impoundment data for both fish and wildlife-related resources were available for only 14 projects (18 percent). Post-impoundment fishery data alone were available for an additional 21 projects (27 percent) and wildlife data alone (generally limited in scope) were available only for an additional 11 projects (14 percent).

In summary, of the 78 projects reviewed, 35 had received some evaluation of post-impoundment fishery conditions, and wildlife-related investigations had been conducted at 25 projects. Both fish and wildlife-related studies had been accomplished at only 14 projects.

MITIGATION ADEQUACY

To date, detailed studies of fish and wildlife planning have been completed and individual reports published for 10 projects, viz: Carlyle (IL); East Lynn (WV); Keystone (OK), (Martin, et al. 1978, 1979a, 1979b); and Lake Sharpe (SD); John Redmond (KS); Littleville (MA); Clark Hill (GA-SC); Ice Harbor (WA); Council Grove (KS); and Okatibbee (MS), (Prosser, et al. 1976a, 1976b, 1976c, 1977a, 1977b, 1978, 1979).

Twenty-nine different mitigation/compensation recommendations were contained in the preconstruction planning reports submitted by the conservation agencies for the 10 study projects. These recommendations fall into six basic categories:

- Operation of selected project lands by state or federal wildlife agency under General Plan by license from construction agency
- land acquisition
- habitat enhancement
- fish/wildlife community manipulation
- provision of facilities to accommodate resource utilization
- continuing investigations.

Management Under License by Wildlife Agencies

Although recommended by the conservation agencies and accepted by the construction agency for all ten projects, only seven currently have some incidental project lands under management license to state or federal wildlife agencies (Table 1). A total of 77,008 acres are specifically licensed for wildlife management to attain mitigation/compensation for the loss of 204,360 acres permanently flooded.

Also, the greater portion of the remaining 153,817 acres of fee lands above conservation pool elevation at the ten study projects support wildlife. However, of this amount, only 39,000 acres, 96 percent of which is located at the Clark Hill and Keystone projects, receive significant land management by the Corps for the specific purpose of enhancing wildlife communities.

The most notable failure of the licensing procedure has occurred at the East Lynn project where insufficient funding to permit development, operation and maintenance has specifically prohibited acceptance of development and management responsibilities by the state wildlife agency. This same restriction has created a similar situation at the Ice Harbor Lock and Dam project.

Land Acquisition

Acquisition of additional mitigation lands was recommended for wildlife purposes in eight of the projects studied (Table 2). No additional lands were requested by wildlife agencies at the East Lynn and Clark Hill projects due to the large acreages above permanent pool planned for acquisition by the Corps.

Table 1. -- Lands flooded, lands acquired in fee and lands managed for fish and wildlife under General Plan and license by state or federal wildlife agency at ten U.S. Army Corps of Engineers reservoir projects

Project	Conservation (summer) pool acreage	Fee land acreage above conservation pool	Acreage under license		Percentage fee land under license
			Land	Water	
Carlyle Lake (IL)	26,000	11,159	8,180	7,500	73.3
Clark Hill Lake (GA-SC)	70,000	83,575	28,473	4,597	34.1
Council Grove Lake (KS)	2,860	3,120	1,538	1,100	49.3
East Lynn Lake (WV)	1,005	23,527	0	0	0
Ice Harbor Lock and Dam (WA)	9,200	6,624	0	0	0
John Redmond Reservoir (KS)	9,400	20,810	18,137	1,841	87.2
Keystone Lake (OK)	26,020	49,308	12,280	3,220	24.9
Lake Sharpe (SD)	55,800	24,142	1,200	0	5.0
Littleville Reservoir (MA)	275	1,405	0	0	0
Okatibbee Lake (MS)	3,800	7,155	4,980	316	69.6
Totals	204,360	230,825	77,008	18,102	33.4

le 2. -- Fish and Wildlife Service (FWS) land acquisition recommendations and subsequent disposition at 10 Corps of Engineers (COE) reservoir projects

	FWS acquisition recommendations		Subsequent acquisition disposition				
				Not implemented			
	None	Fee acquisition	Implemented	Pending funding	Withdrawn by FWS	No state action	Rejected by COE
mber of projects	2	8	1	1	1	2	3
rcentage	20	80	13	13	13	24	37
reage involved	--	--	2,800	1,100	3,400	3,260	9,878

even of the proposed acquisition packages speifically identified those lands considered ecessary to avert wildlife losses. The recomended plans totalled 16,530 acres in fee and onversion of 2,800 acres of planned easements o fee acquisition. The Carlyle Lake report equested consideration be given to additional cquisition for wildlife purposes, but failed o provide specific locations and acreages.

Unilateral rejection of acquisition recomendations by the construction agency occurred t Council Grove (725 acres), Keystone (9,145 cres) and Carlyle (unspecified request). The irst two situations, totalling combined reuests for 9,870 acres, were rejected based upn unfavorable benefit to cost ratios. Based n hunter-day use expectations ranging from 0.5 o 1.7 trips per acre annually for the mitigaion lands, the benefit to cost ratio calculaed by the Corps for both of the projects was .14:1.

At the Okatibbee Lake project the conseration agencies recommended acquisition in fee f 2,800 acres rather than acquiring easement n these lands as was planned. The project deign was eventually altered to accommodate aditional water storage and included acquisition n fee of the 2,800 acres in question, thereby atisfying the Fish and Wildlife Service's reommendation.

At the John Redmond project in Kansas, the ,400 acres requested to enlarge the U.S. Flint ills Refuge operated on project lands was proecuted successfully through the complex Corps-stablished justification procedure and receivd Congressional authorization in 1965. Howver, in 1970 the Fish and Wildlife Service deermined that the existing incidental project ands under license were adequate for their eeds and asked the Corps to desist from acquistion of the additional authorized acreage.

The land acquisition request at Lake Sharpe as strangled by institutional disagreements. willing seller acquisition constraint was imosed by South Dakota and, citing procedural ifficulties, later rejected by the Corps. The 275 acre Littleville project acquisition proposal (600 acres) was characterized by totally inadequate coordination between conservation agencies. The resulting fractured proposal never received serious consideration nor active support of the affected federal agencies. Ice Harbor Lock and Dam has been the object of sporadic mitigation planning for 20 years. Acquisition of mitigation lands has not yet been accomplished although 23,000 acres of easement lands and 1,100 acres of fee lands are included in the authorized compensation plan for the four projects on the Lower Snake River.

Habitat Enhancement

Land acquisition, while an essential ingredient in fish and wildlife mitigation, is not the sole solution. The amount of food, water and cover, and ultimately the wildlife community, on any particular piece of real estate can be manipulated and enhanced. Habitat enhancement entails development, operations and maintenance. While fishery habitat enhancement recommendations (in the form of minimum flows, standing timber, selected discharge elevations, elimination of pollution, stable lake water levels during spawning season, bank erosion control and minimum conservation pools), appeared frequently in preconstruction reports; equivalent wildlife-related recommendations were seldom proposed by the conservation agencies. In fact, except in the case of the more recent mitigation planning for the Ice Harbor project on the Lower Snake River, only two recommendations specifically designed to enhance wildlife habitat were ever provided by the Fish and Wildlife Service, viz: fencing and subimpoundment construction. Fencing to control grazing by domestic livestock was recommended at Lake Sharpe, Council Grove Lake, and Keystone Lake. These recommended developments were rejected by the construction agency. The sole request for waterfowl subimpoundment development was later withdrawn when interest waned in a Federal wildlife refuge at the Clark Hill project. No significant development has occurred at Littleville Reservoir, East Lynn Lake and Lake Sharpe. State wildlife agencies have spent large sums of money for habitat development to recover project-associated wildlife losses at Carlyle Lake, Council Grove Lake, Keystone Lake, Okatibbee Lake and Clark Hill Lake. The Flint Hill National Wildlife Refuge on the John Redmond Lake project has been financed by the U.S. Fish and Wildlife Service. Only at Ice Harbor has wildlife mitigation financing been provided by the construction agency.

Fish/Wildlife Community Manipulations

Infrequently, activities to manipulate and improve resource communities directly have been recommended by conservation concerns. Fisheries-related activities of this type include selecting and clearing seining areas for potential non-game fish harvest, chemical reclamation of feeder streams prior to reservoir filling to facilitate establishment and expansion of more desirable fish species, and construction of fish hatcheries. The only example of the application of direct wildlife community manipulation was a recommendation on the Lower Snake (Ice Harbor) to establish a game bird farm for the rearing of birds to be released to support interim recreational hunting pending development of habitat capable of supporting greater game populations naturally. Game farm pheasants are also used to help meet user demand on Carlyle Lake lands, but these birds are not reared at project expense.

Resource Utilization Improvements

Public access facilities, such as parking areas and ramps used by both general water-oriented recreationists and anglers, usually received adequate attention during the planning and construction phases. However, specialized hunting and fishing access needs frequently received less attention. Public access problems in important tailwater habitat received special consideration in the preconstruction planning reports for only the Okatibbee and East Lynn projects. Access to the tailwaters has been provided at all projects, although belatedly in most instances. Inadequate hunter access has been identified as a problem at the Okatibbee, Ice Harbor and Keystone projects.

Zoning of lands and/or waters was recommended at 50 percent of the projects investigated and greater use of zoning has consistently been recommended by fish and wildlife operational staff. Boundary marking to clearly identify public lands was recommended only for the Keystone project.

Continuing Investigations

An accumulated record of research at existing projects to document their relationships to and within the affected ecosystem and their associated societal values would permit improving the difficult planning decisions involved in site selection, design, construction, and operation of future water development projects. Unfortunately, few such studies have been recommended or carried out. Post-impoundment follow-up studies were recommended by the Fish and Wildlife Service in the preconstruction reports for only 20 percent of the projects studied. Three projects received cursory follow-up investigations which generally only reported physical implementation of recommended actions. These follow-up reports were prepared for Clark Hill Lake (1960), Littleville Reservoir (1973) and Okatibbee Lake (1976).

Although the 10 evaluated projects were among the most completely documented Corps projects in terms of fish and wildlife studies, comprehensive post-construction analyses of these resources and related recreational use had been compiled only for Ice Harbor Lock and Dam as part of the Lower Snake River Compensation Plan.

ACCURACY OF PREDICTIONS

Estimates of without-project hunting and angling use and predictions of post-construction project use were usually presented in the Fish and Wildlife Service planning reports submitted to the Corps. These project planning reports also occasionally presented estimates of extant and predicted fish and wildlife community densities, particularly for waterfowl.

The accuracy of the predictions, as evaluated by comparison with subsequent post-construction survey estimates, proved to be highly erratic. Predictions of adverse project effects on the big game community (comprised of white-tailed deer in most of the projects examined to date) were substantially overestimated in most instances. In fact, of the seven projects with usable data, all but one supported a greater number of post-construction hunter-days for deer (a minimum of 176 percent more) than predicted in the Fish and Wildlife Service planning reports. Post-construction deer hunting was restricted to bow hunting and primitive firearms on the Okatibbee Lake project, the only project which experienced less deer hunting effort (82 percent) than was predicted. In retrospect, it appears that the Fish and Wildlife Service planners did not anticipate the rapid increase in deer abundance that occurred generally throughout the Nation during the period (1945-1965) these reports were compiled. Except for the Ice Harbor Lock and Dam project, impacts on deer abundance were restricted to the immediate area of the project and appeared to be directly related to the amount of deer habitat lost due to impoundment and associated project development. The loss of a "small" area of winter deer range (supported an estimated 20 deer) at the Ice Harbor project resulted in an apparent total loss of deer in the surrounding area following impoundment.

In contrast to big game, available post-construction use predictions and/or fish and wildlife population abundance estimates for upland game, waterfowl, and fish did not exhibit consistent bias. Fish and Wildlife Service planning report predictions overestimated (300 to 490 percent) post-construction upland game hunting for three of the seven applicable projects; underestimated hunting effort and/or harvest for two projects (69 and 77 percent); and were within 25 percent of the actual post-construction harvest at the remaining two projects.

Post-construction waterfowl hunting and/or population abundance predictions were overestimated (120 to 2,700 percent) for three projects; underestimated for two projects (59 and 77 percent); and within 33 percent of the prediction for the remaining project. One instance of overestimation (John Redmond) possibly reflected the desire of the Fish and Wildlife Service planners to assure implementation of their recommendation for the establishment of a waterfowl refuge in conjunction with the project.

Post-impoundment angling use predictions were significantly overestimated for five projects (37 to 155 percent); underestimated for three projects (66 to 81 percent); and within 23 percent of the predicted value for one project.

It should be emphasized that this evaluation of the accuracy of the planning report predictions, of necessity, assumed a "face-value" assessment of the validity of both the pre-impoundment and subsequent post-construction survey estimates. Substantial deviation from actual values of either the pre- or post-construction data would seriously prejudice the findings as presented.

CONCLUSION

This interim review documents the paucity of quantitative data available for evaluation of water resource development impacts and highlights the inadequacy of past fish and wildlife planning at Corps of Engineers reservoir projects. This circumstance emphasizes the compelling need for the development of improved fish and wildlife resource assessment methodology and underscores the importance of implementing carefully designed follow-up studies in order to properly assess the impacts of water resource development projects on fish and wildlife.

Subsequent systematic application of data amassed through such an expanded basic research program would contribute greatly to future water resource development siting, construction and operation decisions. An ability to predict gains and losses to fish and wildlife resources would constitute a major scientific and institutional advancement in planning for conservation and enhancement of fish and wildlife resources. Conversely, continued efforts to develop predictive strategies without accurate introspective data may prove time-consuming and may provide results of questionable value.

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The Status and Success of Fish and Wildlife Mitigation in Western Water Resource Projects
1946 - 1979[1]

Gerald C. Horak[2]

This paper summarizes six research projects analyzing the formulation, acceptance, and implementation of 600 fish and wildlife recommendations as well as the effectiveness of these measures to preserve or improve populations and habitats in twenty states west of the Mississippi River. Recommendations are offered to improve the effectiveness of fish and wildlife measures.

INTRODUCTION

For the purposes of this paper fish and ldlife mitigation is the process of reducing sses of, compensating for losses, or even imoving fish and wildlife resources associated h the construction and operation of federally mitted or constructed resource development ojects. The successful consideration of fish l wildlife in any given set of project goals primarily dependent on the interaction of e U.S. Fish and Wildlife Service (FWS) and ate fish and game departments and construction permit agency in their application of the sh and Wildlife Coordination Act (FWCA).

Historically, the bureaucracy created by CA and aided by the National Environmental licy Act has not, however, provided for *sysmatic monitoring* of the coordination and imementation process. The proposed rules pubshed in the *Federal Register* 18 May 1979 to minister FWCA do address *systematic monitoring* this process for projects which are new arts, in planning, or not substantially cometed. Therefore, it is essential for FWS and ate fish and game agencies to check on the clusion and implementation of their recommentions for projects covered by the proposed les as well as for completed projects. Senor William Proxmire asserts (U.S. Congress 69) that, "We know little about the kinds of inputs and program structures which will yield the outputs we desire and if we ever hope to generate improvements in programs...., we must have follow-up evaluation."

Decision makers in fish and game agencies have not gathered the retrospective information so essential to improving fish and wildlife recommendations and procedures (Davis *et al*. 1973). The failure to obtain this information stems from the constant pressure to give priority to ongoing and new projects (Horak, 1974). Therefore, *ex post* analyses are needed to provide fish and wildlife decision makers with feedback on the consequences of their previous decision. This type of feedback is readily provided for other outputs of resource development projects such as hydroelectric power and irrigation.

This paper summarizes six research projects (Davis *et al*. 1972, Horak 1974, Horak 1973, Nelson, *et al*. 1976, Nelson *et al*. 1978a, and and Nelson *et al*.1978b) analyzing the "track record" of 578 fish and wildlife measures to preserve or improve populations and habitats associated with 146 dams, reservoirs, or projects sponsored by the Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, Corps of Engineers, Federal Energy Regulatory Commission, Forest Service, and Soil Conservation Service. These projects are located in twenty states west of the Mississippi River.

FINDINGS

The achievement of successful measures for the protection of fish and wildlife resources is a complex, multifaceted process. In its simplest form, the process consists of three steps: formulation of a fish and wildlife recommendation by state and federal fish and wildlife agencies; bargain for a measure acceptable to the fish and wildlife agencies and consistent with the objectives of the project sponsored by the construction or permit agency; and implementation and maintenance of the accepted measure by the agency operating the project.

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[1] Paper presented at the Mitigation Symsium, Fort Collins, Colorado July 16-20,1979.

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Under FWCA recommendations are formulated by fish and game agencies on the basis of investigative methodologies. This task is complex and involves many decisions which clearly affect the successful attainment of FWCA's intent. Generally recommendations have not been based upon site-specific quantitative hydrological and biological investigations, but rather rely upon qualitative data. The biological objective of fish and wildlife recommendations has been to maintain rather than enhance fish and wildlife. The biological target of recommendations has been the preservation of fishery or wildlife habitat, and is rarely directed at a population class or life cycle.

Bargaining for the adoption of a fish and wildlife recommendation is a process whereby the fish and game and the sponsoring agencies interact in determining the measures to be implemented at a particular dam, diversion, or project. This process might occur before, during, or after the formulative process. Of the 578 measures analyzed 26% were rejected. However, for every five measures requested, three measures (63%) are agreed to without modification. After modification, the remaining recommendations (11%) were accepted by the sponsoring agency. In a study of instream flow requests (Nelson et al. 1976), the data show that flow requests made after the project began operating frequently resulted in poor bargaining success; whereas, flow requests generally made in early project development were usually accepted.

The data also is analyzed according to the type of measure requested. Lower acceptance rates were reported for minimum flows and fluctuation control requests, which, if implemented, constrain the maximization of other project objects such as irrigation by either requesting a minimum amount of water be continuously released through the dam or by requesting limits to daily fluctuations in flow. Requests for fish hatcheries and nursery and rearing ponds enjoyed a high rate of acceptance. Even though the cost involved in constructing and maintaining them may be substantial, these measures were almost unanimously accepted, because they greatly enhance the value of a stream fishery as well as being extremely visible and pleasing to the public. Recommendations for barrier dams, fish screens, fish stocking, and fish eradication also had high acceptance rates. Aside from aiding the fish resources biologically, each of these measures has direct recreational benefits. For example, barrier dams prevent rough fish from competing with certain game fisheries while allowing the movement of andromous fish.

One out of every two requests for land acquisition was rejected. The dominant factors for rejecting land acquisition are funding limitations and state and local conflicts. Land acquisition must be authorized by Congress, and in many cases Congress neither authorizes such acquisition nor provides sufficient funding for purchasing the amount of lands requested by the FWS. Many of these recommendations were rejected because of state and local conflicts. State governments and local factions generally are opposed, either because of cost-sharing requirements or the need for condemnation proceedings.

Implementation of a fish and wildlife recommendation is the process by which a sponsorin agency complies with an accepted measure. Bes examining the discrete yes or no question regar ing implementation, the rate, degree, and succe of implementation will be discussed. Of the 57 originally requested 64% are ultimately implemented; whereas, 87% of measures agreed-to by sponsoring agencies have been implemented.

A means to gauge the rate of implementati of fish and wildlife measures is to compare th progress of expenditures for fish and wildlife measures to the progress of expenditure on oth project purposes. For each year of the construction period it is possible to compare obl gated funds to estimated funds for both fish a wildlife measures and the rest of the project. Through a comparison of the two sets of statistics, it is possible to chart fish and wildlif funding status relative to other project purpo s. Such a comparison was accomplished for 12 Bure of Reclamation projects (Davis et al. 1973). The most noticeable result is that fish and wi life mitigation measures requiring funding rar y are initiated as early as other project activities. Although lagging initially, fish and w d life mitigation shows a tendency to catch up w h the remainder of the project as it progresses completion. In 6 of the 12 projects studied, fish and wildlife mitigation expenditures have reached a level which equals or exceeds that i other project activities.

Not all mitigation measures involved expe ditures. The degree of implementation of nonexpenditure measures such as minimum flows or pools can be particularly hard to trace. Usua y investigators have relied on the work of field staff of the involved agencies. This is less than satisfactory, since their observations ar often casual. Preferred documentary evidence would include frequency with which minimum flc requirements have been met, reservoir pool lin s violated, flow fluctuation restrictions violated, and other non-financial measures of implementation.

For one class of these measures, minimum flow requirements, the compliance of 30 flows agreed-to by the sponsoring agencies has been documented, usually on the basis of U.S. Geological Survey streamflow gaging records (Nelson *et al.* 1976). A flow was considered to have been violated if more than 5% of the daily average flows (18 days a year) were below the level of the flow agreement. Only two-thirds of the agreed-to flows complied with this criterion. The frequency of these violations range from 22 days a year to 172 days a year with an average frequency of 85 days a year.

The effectiveness of implementated measures is another test of FWCA success. Although a number of approaches could be followed, in a study for the Fish and Wildlife Service (Nelson *et al.* 1978a) the effectiveness of measures was evaluated on the basis of how well the measure achieved its intended purpose. Each application of a measure was classified as successful, marginally successful, or unsuccessful. If an individual measure apparently accomplished a major proportion of its intended purpose, it was classified as successful. If only a moderate part of its intended purpose was attained, it was classified as marginally successful. A measure was deemed unsuccessful if only a minor portion of its intended purpose was realized. This study ranked 61% of the 432 measures requested as ultimately successful or marginally successful. Furthermore, 93% of the 28 measures implemented has some degree of success associated with their implementation. However, it must be noted that the procedure used to arrive at this judgement relied heavily on qualitative data because quantitative pre- and post-impoundment studies were rarely available.

CONCLUSIONS AND RECOMMENDATIONS

My research findings strongly suggest changes in the fish and wildlife recommendation process. These findings specifically support changes that would: (1) Require specification of measures and consider the need for additional pre-or post-construction investigations; (2) Provide for post-construction studies in evaluating proposed and existing projects to determine with greater accuracy the impacts of the project on fish and wildlife resources; (3) Require the sponsoring agency to advise the Secretaries of Interior and Commerce and the respective state agency of its proposed disposition of fish and wildlife recommendations, including their implementation schedule; (4) Establish procedures that would ensure full consideration of recommendations offered in post-construction studies and require the sponsoring agency to report their action on the measures; (5) Provide Congress and the Office of Management and Budget with annual progress reports documenting efforts undertaken to implement fish and wildlife measures; (6) Ensure that land and waters for fish and wildlife are acquired in phase with other project features; and (7) Require that the public be given every appropriate opportunity for participation in planning. Points 1 and 2 involve strengthening of the formulation process; the bargaining process would be improved through points 3 and 4; the implementation of measures is enhanced by points 5 and 6; and point 7 involves the total process.

The proposed rules published 18 May 1979 in the *Federal Register* to establish uniform procedures for federal agency compliance with the FWCA incorporated many of these points. However, these proposed rules do not require monitoring the implementation and effectiveness of fish and wildlife measures on completed projects. The proposed rules state that on completed projects any agency administering wildlife resource properties *may be* requested to prepare annual reports to action and federal wildlife agencies demonstrating how authorized wildlife conservation measures and the General Plan are being implemented and how compensation and enhancement is being achieved. Also, post-construction studies should evaluate the impact of any non-implementation of measures recommended by wildlife agencies, as well as the effectiveness of implemented measures. Thus, the proposed rules generally address the issue, stating annual reports *may be* requested and post-construction studies should evaluate the effectiveness of implemented measures. As yet, however, efforts have not been directed toward ensuring that fish and wildlife measures, once agreed-to through interagency bargaining, are actually maintained and effective.

Research has shown that third parties (e.g. state fish and game agencies, concerned sponsoring agency and FWS staff, environmental interest groups, development groups, and Congress) have been an important variable affecting the ultimate implementation of fish and wildlife measures. Positive aspects of third-party involvement must be institutionalized in order to be truly effective for two reasons. First, if these actions are institutionalized, they would apply to all projects rather than having a random application. Second, the character of the bureaucracy is such that it responds to requirements that are legally specified. The data indicate that the guidelines set up by the current legislation are not sufficient to enlist the bureaucracy to ensure implementation and maintenance of fish and wildlife measures.

To ensure that fish and wildlife recommendations are implemented sponsoring agencies should be required to submit an annual report to Congress and the Office of Management and Budget which summarizes for each project in planning, under construction, or in operation during the preceding fiscal year the implementation status of fish and wildlife measures. This report would ensure that systematic monitoring of fish and wildlife recommendations would occur during the entire planning process.

A large number of fish and wildlife measures have been agreed-to on completed projects, but Congress or other interested parties have no way of determining the degree to which the measures have been effectively implemented. Since many of the fish and wildlife concerns currently expressed, were not of vital interest during the development of past resource projects, many existing fish and wildlife measures are inadequate for fish and wildlife protection. In view of this situation, modification of the measures implemented or the implementation of additional measures must be considered to protect the existing fish and wildlife resource. For completed projects, the sponsoring agencies should be required to provide the same accounting on fish and wildlife measures that is provided for other project purposes such as irrigation and hydroelectric power. For example, the Bureau of Reclamation annually publishes detailed statistical data for each project concerning acreage, yield, production, and gross value of crops grown; land utilization; water distribution; and status of Reclamation land; but only publishes a summary of environmental enhancement on Reclamation lands.

Research has shown that monitoring fish and wildlife measures on operating projects can significantly improve their degree of implementation. Where gage records are reviewed on a regular periodic basis, such as for projects in Montana and Wyoming, there are no significant violations. Review of hydrologic records on Oregon's Baker Project (Powder River) prompted the dam operator to release the required flow following an extended term of substantial violations. Therefore, if information on the degree of implementation of minimum flows, pools, fluctuations, or other such measures was required annually, their respective implementation rates will probably improve dramatically. Furthermore, if the proper measures are formulated and agreed-to, then systematic monitoring should ensure the effective preservation of fish and wildlife as well as reducing the possibility of costly restorative action resulting from the measures not being fully implemented.

For one group of measures (minimum flow, minimum pool, pool and flow fluctuation control, etc.), a national monitoring system could be developed permitting water resource planning agencies to utilize existing U.S. Geological Survey computer files of streamflow, p levels, and water quality data to furnish cont uous surveillance. Water quantity measures account for 25% of the measures requested. Simi systems could be designed for other aquatic ar terrestrial measures.

Once recommendations are formulated, offe negotiated, and accepted by the project constr tion or operating agencies, the water resource planning process seems to terminate. There is systematic surveillance and monitoring to ensu that reservations established by formal or informal interagency agreement are actually adhe to by the operating agencies, or that serious ficiencies are disclosed as a basis for renewe bargaining or actions to improve compliance. planning and management loop for achieving wat flows and levels for fish and wildlife, recreation, water quality and other purposes is incomplete; no systematic feedback is available to guide the formulation and bargaining process toward more effective, more binding interagency agreements.

A national surveillance system could be designed and made operational to report the current quantity and quality of flows and poo and enable better water management for fish ar wildlife and many related purposes, including recreation and water quality. This system wou provide access to a U.S. Geological Survey on-line computer program which can be adapted to report USGS gaging data in the form of reliab hydrological and water quality indicators of current environmental stress on aquatic and riparian biota. This data reported periodica can disclose current violations severe enough warrant renewed interagency bargaining to pro ly improve compliance with flow reservations fore lasting environmental degradation can oc The purposes, applications, and prospective u of the proposed surveillance system span the tivities of all water resource planning and m agement agencies.

The overall objective of the proposed national monitoring system is to strengthen the information technology of water resource planning agencies so as to increase management ef tiveness of utilizing on-line data banks to m imize environmental damage to fish and wildli recreations and other allied resources. The tem would serve several objectives of specifi concern to water resource planning agencies:

- For purposes of long range planning, t system would aid the development and r finement of methodologies for determin water needs for fish and wildlife maintenance by comparing predicted water needs versus actual quantities and ecological effects

- For purposes of selecting short-range planning priorities, water resource units and associated ecosystems under special stress from energy resource development could be identified
- For purposes of current resource management, the extent, duration and frequency of deficiencies and violations with respect to recommended and reserved water quantities in water resource and related energy development projects could be determined as often as is warranted.

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Mitigation Under the Corps Regulatory Program [1]

Arnold Banner[2]

Abstract.--The Fish and Wildlife Service often requires mitigation for private development in wetlands needing Federal permits (River and Harbor Act, Clean Water Act). Cumulative impact of small projects and expansion of jurisdiction to freshwater wetlands has made this program increasingly important. Mitigation for permitted work (and restoration of violations) is like project mitigation in using simplified HEP, and off site or structural enhancement, but avoids long-term management.

Mitigation is commonly associated with Federal projects but is also appropriate for impacts from private activities under Federal jurisdiction. Within the Corps of Engineers regulatory program,[3] the Fish and Wildlife Service rountinely evaluates the environmental effects of development activities in wetlands. Under the Fish and Wildlife Coordination Act, the Fish and Wildlife Service is consulted for its concerns over permit issuance. Also, the Memorandum of Understanding between the Secretaries of Interior and Army established a procedure to resolve difference of position. The majority of works regulated by the Corps are individually small, but their cumulative impact can be important. Permits are needed to authorize dredging and filling and, according to a recent court decision,[4] even to plow or clear a wetland of its natural vegetation. With this broader Corps jurisdiction over freshwater wetlands, we are encountering private projects up to 20,000 acres in extent.

Mitigation under the Corps regulatory program generally takes the form of permit conditions which require either additional work to locally enhance environmental values or to eliminate damaging aspects of private projects. The Service can recommend denial when mitigation does not appear to be feasibl or acceptable to the applicant and project impacts are expected to be significantly harmful to habitat values, especially over th long term.[5]

When a project is performed without the necessary permits, the Corps is required to solicit recommendations from Federal and Sta resource agencies. Responses may range from suggestions that after-the-fact approval woul be satisfactory all the way to recommendation for extensive restoration or mitigation. The detection and resolution of such violations i necessary not only for environmental mitigati but also to ensure compliance with the permit program. Prosecution goals thus may include restoration, civil fines and criminal penalti Because the work has already been accomplishe and restoration costs and loss of a portion all of the project are not in the owner's interest, the defendant frequently challenges restorations in court. Criteria by which restorations are judged include feasibility, equitability and impact on third parties or innocent bystanders.

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[1] Paper presented at The Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

[2] Environmental Specialist, Fish and Wildlife Service, Vero Beach, Florida.

[3] Regulatory Program of the Corps of Engineers, 42 FR 37122-37164, Based upon the River and Harbor Act of 1899, and the Clean Water Act, amended 1977.

[4] The Avoyelles Sportsmen's League et al. vs. Clifford L. Alexander, Secretary of the Army et al. 78-1428-Civ.-N.S.,W.D.La. (May 4, 1979).

[5] Review of Fish and Wildlife Aspects of Proposals in or Affecting Navigable Waters (40 FR55810-55824)

The most interesting part of this whole
gram is the mitigation which is proposed and
omplished by permit or by restoration order.
order to propose mitigation, we first must
ognize the constraints of the program and so
ntify available options. The River and
bor Act and Clean Water Act which the Corps
inister concern development in wetland or
ecting the course, condition or capacity of
igable waters. So we generally are miti-
ing for wetlands and shallow-water habitat,
ept that uplands which affect navigable
ers (including effects on environmental con-
ion or biological capacity) also may be
ulated (McIntosh and Mehta, 1977). Even
n wildlife usage may be our paramount concern
a given property, fishery values and water
lity obviously must be addressed. Mitigation
ions then take the form of locally enhancing
er retention, circulation, or quality and the
rovement of substrate characteristics and
th in order to promote growth of beneficial
nts (Banner, 1977).

Permit mitigation or conditions generally
restricted in the following ways: Permit
igation should not take the form of land
ps or donations when the land proposed for
ation already is subject to Federal protec-
n. Land not so restricted rarely is offered
, in any case would not be the same habitat
e. Of course, there are other more practical
trictions:

1. Work must be accomplished on site
hough additional purchases specifically for
igation works are possible. This is in con-
st to project mitigation which commonly
olves purchase of outside lands and manage-
t to enhance for selected species.

2. The applicant must be able to make
eficial use of his property or there is no
son for him to do the mitigation. In the
e of unauthorized work, it is simpler to
otiate restoration when some of the owner's
ectives can be woven into the final plan.
not, restoration will have to be enforced.

3. Measures will have to be self
taining and of a permanent nature. Manage-
t schemes are to be avoided since manpower
not available for checking up on projects
er their completion. This also is in con-
st with management methods common to project
igation. Mitigation through structural
sures have the benefit of durability but if
ccessful, lack the flexibility which is
rent in a management plan.

After all of these limitations, what options are left? Some take the form of retention ponds or waterways shallow enough to ensure growth of emergent or submerged aquatic plants. Connections should be broadly established with neighboring waters and habitat diversity should be encouraged. Water bodies with naturally high pigmentation or turbidity should be supplied with sufficient marsh area to act as biological filters, supply detritus and offer fish nursery areas. Fish and Wildlife Service comments on permits frequently emphasize the need for shallow-water habitat. This may at first appear to overlook the need for deeper water. But remember, most wetlands development takes place in the shallows and high marsh, and so mitigation for these losses is most often called for. Emergent vegetation is common to such sites, and landowners would rather have either dry land to farm or build on, or open water to boat on or to present "an attractive vista". Yet as you can see, the options, restrictions and habitat needs all point to the enhancement or creation of shallow waters, marsh or wooded wetlands as mitigation for Corps permits.

How do we accomplish this? Basically through the same mechanisms causing the project impacts - dredge and fill. We have mitigated losses by dredging connections to other bodies. We have created marsh and shallows by dredging uplands and transitional areas. We have filled deep canals to allow revegetation by seagrasses and by emergent vegetation. Some of these mitigative schemes include dredging which creates new shallow habitat and at the same time provides fill which is placed in excessively deep channels.

As an example of improving water quality (and thus habitat) through improved circulation, I present one of our older cases in the Florida Keys (fig. 1). The unauthorized work consisted of three 1,000-foot long canals which were joined to an entrance canal connected to tidal waters at one end only. The percent of resident water exchange on each tidal cycle was very small in the original work. Much of the canal bottom had become vegetated with valuable seagrasses, so plugging off or refilling them was an undesirable solution to us as well as to the developer. Because the property was a cross-section of the island, we instead modified the system into a flow-through network, taking advantage of tidal differentials across the island. However, the bay on the far side was very shallow (about one-fourth of the canal depth), and water quality was poorest in the deeper reaches of the canals. While surface waters could be exchanged by just interconnecting the canals, the problem was to flush out bottom waters.

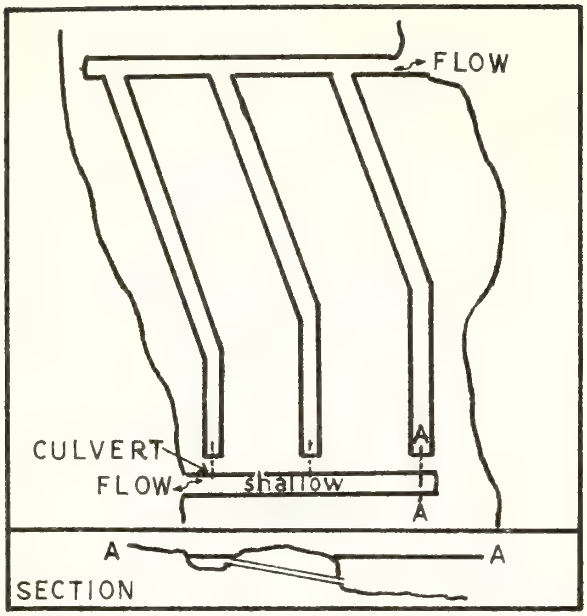

Figure 1.--Inclined culvert modification to improve water circulation

A novel solution proved effective. Large culverts were emplaced connecting the canal dead ends with a broad shallow ditch or channel. The latter was dug across a barren rocky upland, and since has become vegetated by seagrasses and marine algae. The culverts were installed on an incline, from the canal bottoms upwards to the ditch bottom. Tidal differences overcame any density gradients. Strong flow through the culverts and mixing within the canals has been demonstrated using marking dyes. The work was environmentally effective and, moreover, was so inexpensive, the owner complied voluntarily.

As an example of wetlands creation from disturbed transitional area, I offer a case just up the road from our field office. The owner had filled two acres of tidal mangroves plus adjacent wetlands at that time above Federal jurisdiction, but he didn't fill it sufficiently to prevent sparse recolonization by high marsh species. As settlement, we allowed him to "reclaim" this marginal area in return for creating a 5 acre tidal pond (fig. 2a, b). Within its first year, samples have shown the pond to be a nursery for black drum, snook, ladyfish, silversides, penaeid shrimp and blue crabs. Again, this was an out-of-court settlement with benefits to both parties.

Figure 2a--Marginal wetland to be partly developed, partly enhanced.

Figure 2b--Shallow tidal pond created as mitigation on the property above.

A third example, mitigation by dredging and by filling, has not been settled so amicably. The case U.S. vs. Moretti is relatively famous (notorious?). Moretti dredge deep "upland" canals and filled shallow water in Florida Bay; the mitigation plan is to remove the fill and replace it (plus many thousands of cubic yards from elsewhere) in deepe portions of the canals. Refilling is necessa to correct water quality problems and compens for habitat losses. The environmental argume run up against economic arguments in court ("equities"). For fish and wildlife values t "receive equal consideration" with restoratio costs, their benefits to the public must be demonstrated to the judge.

Recently we have used a simplified version of the Habitat Evaluation Procedures developed by the Service as a tool to quantify mitigation needs for permits. This also should provide good estimates of resource losses and rank various mitigation plans for court cases.

As seen in my second example, above, mitigation of coastal high marsh can be relatively straight forward. Intermittently flooded areas tend to be very salty, frequently have poor soils and support vegetation of unknown value to fisheries. Salt barrens, blackrush and pickleweed marshes are examples.

On the other hand, as we approach the fresher headwaters of estuaries we encounter a terrific diversity of vegetation. Headwater areas tend to experience strong sedimentary processes, and so are poor locations for waterfront development. When land speculation and development are influenced more by promotion than by common sense, development here can be truly disastrous. Residential development in the form of canal systems reduces the mixing zone to the extent of the dead-end of a canal. Salinity stratification and accumulation of organic sediments ensures that both water quality and habitat are minimized. This is likely to be a situation where adequate mitigation is impossible so we cannot recommend issuance of a permit, and where we must propose restoration of unauthorized work. Similarly, freshwater wetlands are difficult to mitigate. As with projects, the practicality of mitigating losses due to private development decreases as habitat quality increases. In prime habitat, it simply is not feasible to make up for wildlife and fishery losses. This often is the case in conversion of wetlands to agricultural land.

The most challenging cases are just now being approached as Federal jurisdiction over interior wetlands is being explored and identified. The administrative and legal decisions over jurisdiction under the Clean Water Act and the River and Harbor Act are extremely important. It is necessary to recognize that virtually all wetland areas in private and in public ownership which either connect to or even affect navigable waterways (which may be far downstream) are subject to Federal jurisdiction and that any activities which impact these wetlands may require Corps of Engineers permits and thus must offer mitigation or be open to denial.

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Wildlife Conservation Strategy Derived from Case Histories of Ten Federal Water-Resource Projects in the Southeast [1]

Roy K. Wood and Bryan L. Swift[2]

--With a view toward determining prerequisites for a successful conservation effort, case histories were conducted of ten federal water resource projects in the southeast. Of many factors which influenced success or failure, five factors emerged as the most dominant and are recommended as guides in the development of conservation strategy.

INTRODUCTION

The formulation and implementation of wildlife[3] conservation[4] plans for water resource development are complex processes requiring considerable effort, generally, over a long period of time. Many agencies, interests, and individuals are involved, working independently and as a team. Mutual understanding and a willingness to give and to take are fundamental.

Conservationists appear frustrated. Many efforts have not succeeded. In search for answers we conducted case histories of ten federal water-resource projects in the Southeast. Specific objectives were to formulate a set of criteria for evaluating the strengths and weaknesses of a conversation effort and which, in turn, could serve as guides to developing conservation strategy.

The results of this study have yielded information which we believe will be of assistanc to biologists, planners, and cooperating interests. We describe what was accomplished; but, were more concerned with how it was accomplishe A list of factors which had an important influence on the outcome of the conservation efforts is set forth. Concepts materialized which emph size coordination and cooperation rather than litigation; sound planning and logical reasonin rather than biological precision or ideology; p tience and perseverance as opposed to precipito action or frontal assault. And yet, the effect employment of all these practices including confrontation is evident, in the case histories studied.

METHODOLOGY

Selection of Case Histories

The case histories pertained to ten U. S. Corps of Engineers (hereafter, Corps) water projects in the southeastern United States. Seven led to the establishment of national wildlife refuges. Three are failures or partial failure at the date of this paper. The projects studie and the periods during which the Corps and the Fish and Wildlife Service (FWS) were engaged in the conservation efforts ranged from one to 33 years as indicated in the following listing:

Yazoo Backwater Levee Project, MS. . .	.1946-79
Barkley Lake and Dam Project (Cross Creeks NWR), KY and TN.	.1951-63
Lower Auxiliary Channel Project, MS.	.1954-55
Jackson Lock and Dam Project (Choctaw NWR), AL.	.1954-64
Walter F. George Lock and Dam Project (Eufaula NWR), AL and GA	.1955-64

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[1] Paper presented at the Mitigation Symposium, Ft. Collins, Colorado, July 16-20, 1979.

[2] Authors are, respectively: Special Assistant to the Secretary, Southeast Region and Student Assistant, U. S. Department of the Interior, Office of the Secretary.

[3] Wildlife is herein used to imply both fish and wildlife.

[4] Conservation is herein used to imply both mitigation and/or enhancement.

Holla Bend Cutoff Project (Holla Bend NWR), AK	1956-57
Hillside Floodway Project (Hillside NWR), MS	1956-75
Felsenthal Lock and Dam Project (Felsenthal NWR), AK	1957-79+
Tensas-Cocodrie Pumping Plant Project, LA.	1959-79+
Columbia Lock and Dam Project (D'Arbonne NWR), LA.	1970-79+

The geographic locations of projects stud-ed are shown in Figure 1.

For the purpose of our study, "success" as viewed in terms of:

Lands acquired essentially as recommended a principal measure in all plans) and

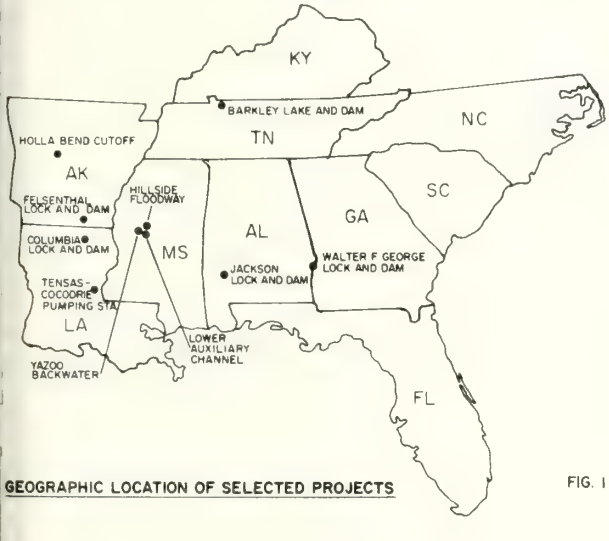
Conservation benefits obtained ssentially as estimated.

"Failure", on the other hand, was viewed n terms of:

Lands not acquired essentially as recom-ended, and

Conservation benefits not obtained essen-ially as estimated.

The geographic locations of projects stud-d are shown in Figure 1.



GEOGRAPHIC LOCATION OF SELECTED PROJECTS

FIG. 1

Case History Reviews

Case history documentation was initiated y gathering and interpreting reports and corre-pondence contained in the files of the Corps, VS institutions, local and private sources. nis was followed up with personal interviews ith Corps, FWS personnel and selected local esidents who were involved in the efforts. A norough historical record was developed, indicating people and events that played important roles in the formulation and implementation of each conservation plan.

In addition to case history information, we compared the wildlife and recreational use of each area, with conservation plan predictions. This information was obtained from the annual reports available from each refuge, except Felsenthal and D'Arbonne National Wildlife Refuges. They were only recently established.

Conservation Effort Evaluation

In order to identify strategic elements necessary for a successful conservation effort, we systematically evaluated each case history. This was accomplished by: (1) developing a simple, but thorough evaluation of the many components of plan formulation and implementation; and (2) compiling a list of factors which appeared to have an important influence on the outcome of a conservation effort. The final product was a questionnaire, which incorporated much of our own experience and input from professional and lay people interviewed. This "Conservation Effort Evaluation" (CEE) provided the format for analyzing the objective and subjective elements of a conservation effort.

RESULTS

The Conservation Effort Evaluation Model

The CEE was structured to recognize the two major phases of a conservation effort: plan formulation and implementation. Under each of these sections, the subject matter is categorized. The entire questionnaire consists of 32 multiple choice "topic" questions, requiring 137 individual responses An example of a topic question with three responses is: "Wildlife resources were evaluated: a. without the project?; b. with the project?; c. with the project modified to include fish and wildlife conservation measures?"

The first half of the CEE analyzes the process and results of plan formulation. It critiques the conservation plan with respect to concepts for good planning contained in "Principles and Standards" (Water Resources Council, 1973) and other planning documents. Specifically addressed in this section are: the presentation of purpose, scope and objectives; the evaluation of wildlife resources; the basis for selecting plans; details of the plan; coordination with various interests; and approval of the planning effort by the agency.

The second half of the CEE analyzes the follow-up effort to implement a conservation plan. It focuses on the intangible elements of a conservation effort. These questions analyze: the role of the various interests in plan promotion; the status of acceptance (support) and opposition to the recommended plan; plan implementation; and the relative "success" of the conservation effort as viewed by the various interests.

The CEE does not derive a final rating or "score", but focuses separate attention to each of the many critical elements in a conservation effort. An evaluation can be performed in approximately 30 minutes. A copy of the complete Conservation Effort Evaluation is available from the Office of the Secretary, Southeast Region, Suite 1412 Richard B. Russell Federal Building, 75 Spring Street, S.W., Atlanta, Georgia 30303.

Evaluation of the Selected Conservation Efforts

The completion and review of the CEE's provided a satisfactory and useful analysis of the conservation efforts. The evaluations which the authors rated independently were very similar suggesting that the questionnaire is objective. The user(s) needed to be informed on all of the important aspects of a conservation effort, but not burdened with quantitative information. The CEE's identified critical strengths and weaknesses of plan formulation and implementation which affected success and/or failure of the selected projects.

To facilitate discussions, the various elements involved in plan preparation and implementation were grouped into five "initiatives" or "thrusts" of a conservation effort. These categories depict the theme, or logical goal, of the specific activities addressed in the CEE as follows:

1) Wildlife plan soundly conceived-incorporates our evaluation of the purposes, scope, and objective of plan formulation and selection, physical plan of development, wildlife resource evaluation, and benefits to be derived by plan of implementation, cost analyses, and plan of administration.

2) Plan coordinated and compatible - a summary of coordination with the action agency in all possible ways but particularly in planning for compatibility of design, scheduling and authorization with other project purposes.

3) Team work accomplished - addresses the overall effort and effectiveness in pursuing, establishing, and maintaining a team effort among national, regional, state and local interests.

4) Support strong and/or opposition overcome depicts the overall status of support and/or opposition among the local citizens, the state wildlife agency, elected representatives and the action agency.

5) Effort sustained - evaluates perseverance and continued effort by the "team" of interests, based on duration and strength of involv ment throughout planning and implementation.

In addition, the "success" of each conse vation effort was determined in two respects:

1) Wildlife plan implemented - relative achievement of planning goals and objectives a indicated by land acquisition as recommended i the plan, tempered by such modifications as we consistent with the wildlife plans.

2) Satisfaction derived - a measure of success combining the realization of wildlife and human benefits as estimated and the expres ed satisfaction of citizens and professionals interviewed.

The relative performance (strong, weak, failure) of the ten conservation efforts in th five initiatives and "success" achieved is summarized in Table 1.

DISCUSSION

The results demonstrate a close relation ship between performance in the major "initiatives" of a conservation effort and likelihood of success. A conservation effort should inte grate strong performance in all of these categ ries to enhance the opportunity for success. Our discussion illustrates these concepts by presenting notable examples, highlights and anecdotes from the case histories.

Plan - Soundly Conceived

Case histories revealed that a soundly conceived plan involves many steps beginning with a clear definition of the purpose and scope of study. Planning objectives of a conservation report should be stated in terms of satisfying human needs or desires, overcoming problems, or taking advantage of opportunities

The conservation effort at the Walter F. George Project was directly linked to local desire and national need for a wildlife manage ment area at or near this project. A similar situation prevailed at other projects studied, particularly, Holla Bend, Barkley and Felsenthal.

Formulation of a sound conservation plan also requires consideration of all details involved with plan implementation, including a d cription of resource requirements (lands, faci iteis, programs, etc) and an analysis of costs including their allocations as called for in Principles and Standards. Such a comprehensi plan of development was not presented for all the unsuccessful projects, but performance did enhance the efforts by providing a sound infor mation base for coordination and promotion.

The plan for replacement of waterfowl facilities inundated by the Barkley Dam and

TABLE I

PERFORMANCE OF CONSERVATION EFFORTS IN FIVE MAJOR INITIATIVES AND OVERALL SUCCESS

	INITIATIVES					SUCCESS	
PROJECT-EFFORT	WILDLIFE PLAN SOUNDLY CONCEIVED	PLAN COORDINATED & COMPATIBLE	TEAM WORK ACCOMPLISH'D	SUPPORT STRONG &/OR OPPOSITION OVERCOME	EFFORT SUSTAINED	WILDLIFE PLAN IMPLEMENTED	SATISFACTION DERIVED
BARKLEY	+	+	+	+	+	+	+
COLUMBIA	/	+	+	+	+	+	?
FELSENTHAL	+	+	+	+	+	+	?
JACKSON	/	+	/	/	/	/	/
HILLSIDE	/	+	/	/	+	+	/
HOLLA BEND	+	+	+	+	+	+	+
WALTER F. GEORGE	+	+	+	+	+	+	+
LOWER AUXILIARY CHANNEL	/	/	/	–	–	–	–
TENSAS – COCODRIE	/	/	/	/	+	–	–
YAZOO BACKWATER	/	+	–	–	/	–	–

+ STRONG PERFORMANCE - STRONG SUCCESS
/ WEAK PERFORMANCE – WEAK SUCCESS
– NEGATIVE PERFORMANCE-FAILURE
? TO EARLY TO DETERMINE

servoir project is an outstanding example of a mplete plan of development. It contained a scription of the wildlife resource potentials the area to be developed, the location and pe of water control structures that would be quired, how these structures would be operated seasonally manipulate water levels, wildlife ods to be planted and harvested, waterfowl use ticipated, cost data, and administrative detail. bitat unit-values were also cited to enable mparison of habitat lost and habitat to be dev- oped. This information was supported by maps d graphs vividly portraying the plan.

Formal concurrence with the plan for Barkley s received from the appropriate states, and ppended to the planning report. At the Jackson, wer Auxiliary Channel and Tensas-Cocodrie pro- cts, where State administration was proposed, tters providing assurance that they would assume ministrative responsibilities were also obtained advance of a General Plan. The State's posi- ion was thereby established and included for the strict Engineer's consideration and report.

Wildlife resources were evaluated variously qualitative terms with the project and with e project modified to include the recommended nservation measures. In either form, this pro- ided a means of measuring benefits and losses tributable to the project, cost effectiveness, d consistency with planning objectives. The nservation efforts at the Lower Auxiliary annel and the Yazoo Backwater were presumably akened by the failure of the plans to present substantial benefits to wildlife and be consistent with local needs.

Plan Coordinated and Compatible

In the case histories studied coordination began early and involved national, regional, state, and local participation. Early involvement allowed concerned interests to express their needs and/or desires for wildlife conservation, so plans could be developed accordingly. Coordination throughout the conservation efforts also fostered good relations with the action agency and public support of the conservation proposals.

At the Walter F. George and Barkley Projects, local citizens were anxious to support the conservation effort, but requested certain modifications in the specific land acquisition recommendations. The compromises were accepted by the Fish and Wildlife Service and served to eliminate potentially severe landowner opposition which may have defeated the plan. At Holla Bend, an intensive informational effort was coordinated at the local and national level, and strong opposition from certain local interests and the General Services Administration was successfully converted to support for a refuge.

The plan for wildlife conservation at the Yazoo Backwater Project contrasts with the successful efforts in its failure to obtain input from local interests. At a public meeting sponsored by the State, total opposition to the plan was expressed because of federal ownership, severe water level manipulation, and planning for waterfowl at the expense of good deer habitat and economically important timber production on the 21,000 acres.

Coordination was obviously lacking, local interests continued to oppose multi-purpose development, and the State went on record opposing the FWS plan.

In the case of the Jackson Lock and Dam effort, which lead to the establishment of the Choctaw National Wildlife Refuge, the conservation plan was formulated in such close cooperation with the Corps that when the wildlife report was submitted, it was accepted and translated into the District Engineer's report with little or no change. Thus, delay in project development was avoided.

Successful conservation measures recommended in the reports reviewed were compatible with the project design, operation and maintenance plans. In some instances, as in the case of the Felsenthal Project, they were inter-dependent. The Felsenthal Lock and Dam is an integral unit of a system of navigation locks and dams in the Ouachita River. The Corps, in the conduct of its studies, determined that the project, based on navigation benefits alone, was not economically feasible. Developed for multi-purpose use, however, including wildlife and recreation, it was feasible. And so the conservationists and navigation interests joined forces, modified the project design to include a fish and wildlife management pool super-imposed on the navigation pool, combined their financial and and political resources and otherwise worked toward common objectives. An incredible achievement is the result.

At the Hillside Floodway Project, the wildlife plan for fee title acquisition of floodway lands for conservation purposes was failing; but later, when it became evident that the same lands were also needed for flood control purposes, it was modified slightly and implemented with little additional expense.

The conservation efforts when successful were also compatible with the schedule of project development. Any major modification, such as the plan to super-impose a conservation pool on top of the navigation pool at the Felsenthal Lock and Dam, must be incorporated early in the planning process. In this case, the recommendation was incorporated by the Corps as an integral part of project design.

The conservation plan at Columbia Lock and Dam was also strategically timed, but in a fortuitous manner. As the Ouchita-Black Rivers Navigation Project (including the Felsenthal plan) was nearing authorization, the Louisiana Department of Wildlife and Fisheries proposed land acquisition in Louisiana as a project feature. Favorable response on the parts of th Fish and Wildlife Service, project sponsors and the Corps was followed by prompt amendment of tl project.

Team Work

The case histories revealed that team wor at the national, regional, and local levels characterized the successful conservation effor

A review of correspondence on the Walter George Project, evidences that a team of dedica professional and lay people was involved from t early stages of this conservation effort throug and following the establishment of the Eufaula National Wildlife Refuge. Sam LeMaistre, a Eufaula citizen, initiated the conservation effort and became the Fish and Wildlife Service focal point for information dissemination. He personally carried the effort to stimulate and coordinate citizens interests and pursue Congressional support for establishing Eufaula National Wildlife Refuge.

A solid team effort was established at Felsenthal by pursuing approval from the Chief of Engineers for a conservation pool as a proje feature early in the planning stage of the project. Later, support for implementation of thi plan and the creation of a national wildlife refuge was rendered by conservation and development interests working together.

Support/Opposition

The cases studied reveal that successful implementation of conservation plans may be attributed in large part to the strength of th local support and/or whether local opposition was overcome or at least neutralized. Events associated with studies to replace wildlife habitat inundated by the Barkley Project, whic led to the establishment of the Cross Creeks National Wildlife Refuge, provide an outstanding example of how opposition can be turned into support.

Another instance where local citizens ceased their opposition and supported the conservation effort when given an opportunity to participate in plan formulation was in the cas of the Holla Bend Project. When field investigations were first begun, the Corps had completed the project and GSA had virtually completed its plans to dispose of the land, which had been created by the cut-off, to private agricultural interests. Local interests continued support of this move until they ealized that the wildlife alternative afforded n unprecedented opportunity for waterfowl retoration in the upper Arkansas River Valley, rkansas. They "turned around" and literally ook the lead in the conservation effort - hich culminated in the establishment of the olla Bend National Wildlife Refuge.

Local and state interests eventually suported efforts at Barkley, Felsenthal, Columbia, alter F. George and Holla Bend. The plan for federal refuge at the Jackson Project was ot opposed by local or state interests and was uccessful; but, the proposed adjacent state hooting area was never established due to nfluential landowner opposition. Continued pposition has prevented the state and the Fish nd Wildlife Service from acquiring this land nd achieving the potential benefits of this roject.

Significant opposition to federal taking nd administration of land defeated the conervation efforts at the Lower Auxiliary hannel and Yazoo Backwater Projects. Despite oordination with the state agency in formulaing the plan for the Auxiliary Channel, strong pposition from local sportsmen and landowners limaxed by a "walk out" during the WS presentation at a public hearing in 1955) esulted in the State's later decision to withraw its support. It was a short-sighted move n the part of the sportsmen. Most of the ottomland forests between the levees have been leared.

Examples such as those described above lead s to believe that gaining support for a conservaion plan is through a strong program of citizen nvolvement at the "grass roots" level.

Sustained Effort

Perseverance and follow through at the ational, regional, and local levels were imporant factors in the success of conservation fforts studied. In the case of the Walter F. eorge special study, eight years and seven onths elapsed between the time the first field nvestigation was initiated until the Eufaula ational Wildlife Refuge was formally dedicated n 1964. Throughout this period local interests aintained their enthusiasm and support for the roject.

In the case of the Felsenthal Project, 20 ears elapsed from the date of the first wildlife tudy report in November 1957 until the national ildlife refuge was established in 1977.

The need for a sustained effort is further llustrated by how failure to maintain strong oordinated support weakened the achievement of onservation success. In the case of the Jackson Project, a high dam proposal which would have inundated over 50,000 acres of bottomlands in Alabama was soundly defeated by a coalition of sportsmen, lumbermen, and landowners. These or other citizens, however, did not follow through and support the fish and wildlife proposals incorporated into the modified project. The Choctaw National Wildlife Refuge was established as recommended but the planned State Wildlife Management area never materialized.

Sometimes perseverance is not enough. In the case of the Yazoo Backwater Project the effort to save a remnant of the productive bottomlands of this area which was initiated in 1946 has been sustained until the present time, a period of 33 years, without success. The effort continues.

Overall Success

This review of case histories reveals that "success" should be viewed in terms of recommended wildlife measures implemented and benefits derived. Table 2 shows that of the 255,900 acres that the FWS recommended be acquired, the Corps did acquire and make available 128,500 acres.

Land acquired and made available for wildlife purposes provide significant indices as to plan implementation. In this sense, the conservation efforts at the Barkley, Columbia, Felsenthal, Hillside, Holla Bend and Walter F. George Projects were highly successful. Waterfowl use of these projects also is substantial. Cross Creeks National Wildlife Refuge, for example, experienced between 3.9 and 5.4 million waterfowl use days annually during the year of record. The predicted use was 3 million. Eufaula National Wildlife Refuge experienced between 1.9 and 4.3 million waterfowl use days annually. The predicted use - about 4.0 million.

The Jackson conservation effort is considered to be a partial success. Despite acquisition of the land recommended for a national wildlife refuge, the plan for state leasing of a public shooting area on adjacent land was never realized. Although the State of Alabama found it necessary to refrain from meeting its commitments, the Corps did install water control structures at project cost to enable future water level management of this bottomland. The failure to implement the entire plan was, at least partially responsible, for the less than predicted waterfowl use at the Choctaw Refuge.

The conservation efforts at the other three projects were failures, or partially so, since no lands were acquired for conservation purposes, (certain structures were authorized, however, and the Tensas Project was relocated which in itself is a major conservation

TABLE 2

LAND RECOMMENDED AND MADE AVAILABLE FOR FISH & WILDLIFE SERVICES BY THE CORPS FOR WILDLIFE PURPOSES

PROJECT	WILDLIFE FACILITY	RECOMMENDED (ACRES)	RECEIVED (ACRES)
BARKLEY	KENTUCKY WOODLANDS NWR CROSS CREEKS NWR	22,200 16,000	7,300 9,000
COLUMBIA	D'ARBONNE NWR	18,000	17,500
FELSENTHAL	FELSENTHAL NWR	65,000	65,000
HILLSIDE	HILLSIDE NWR	22,400	15,400
JACKSON	CHOCTAW NWR	4,200	4,200
WALTER F GEORGE	EUFALA NWR	11,000	11,000
HOLLA BEND	HOLLA BEND NWR	4,100	4,100
AUXILIARY CHANNEL	—	11,000	-0-
TENSAS-COCODRIE	—	11,000	-0-
YAZOO BACKWATER		71,000	-0-
	TOTAL	255,900	128,500

success). Moreover, the conservation effort at the Tensas-Cocodrie and Yazoo Backwater Projects remain active within the FWS, where plans for land acquisition continue to be an important feature. There has been no determination of wildlife losses. Future benefits of these projects without some public control to discourage widespread clearing of the forests are doubtful.

Human satisfaction derived after a project is completed is also viewed as a useful indicator of success.

"Satisfaction" is usually reflected by an atmosphere of support and cooperation that is sustained with continued operation of the facility. The citizens at Eufaula have expressed great pride and pleasure about the existence of the nearby national wildlife refuge. It attracts nearly 250,000 visitors and 50,000 ducks per year - a conservation success by local and national standards. The Corps joined in the festivities of the Eufaula National Wildlife Refuge grand opening, with pride and satisfaction.

Popularity of wildlife facilities was observed at Holla Bend where flocks of 10,000 Canada geese have been restored in the upper Arkansas Valley, Arkansas and American Bald Eagles are common winter residents. Local support for refuge and its program continues to flourish.

The establishment of wildlife facilities at Choctaw and Hillside Refuges has been accomplished with mixed success. Local residents continue to view the refuges as recreational opportunity lo rather than a heritage and opportunity preserve Public use of these two refuges is below their potential, reflecting a lack of awareness of be fits that could be derived from the facilities. The lack of conservation facilities at certain other projects precludes the potential benefits conservation and recreation inherent in them.

CONCLUSIONS

The results of the case history reviews a CEE's lead us to the conclusion that the follow factors had a favorable influence on the conser tion efforts and should be employed in the deve opment of conservation strategy:

1) development of a soundly conceived pla to satisfy legitimate human needs and/or desire

2) formulation of a plan which is compati with project design and scheduling, including timing of plan presentation;

3) early and coordinated involvement of a interests (national, regional and local--public and private) in plan formulation and implementa tion to establish a team effort;

4) favorable support and/or lack of stron opposition from local conservation and developm organizations;

5) perseverance and follow through by the team to insure authorization and implementation as recommended.

Although our study was limited to Corps water projects, we believe that the findings may be applied generally to developing and executing conservation strategy.

REFERENCES

Water Resources Council. 1973. Establishment of Principles and Standards for Planning Water and Related Land Resources. Federal Register 38(174):24778.

ACKNOWLEDGEMENTS

This paper was made possible through the outstanding cooperation, assistance and support received from all of the persons contacted. Special recognition is due the following citizens who were interviewed and played key roles in the successful conservation efforts studied: Robert Sexton and Corrine Whitehead (Barkley Lake and Dam); Vaskell Carter, Jack Lee and H. K. Thatcher (Felsenthal Lock and Dam); Sam LeMaistre (Walter F. George Lock and Dam); Paul Gardner, Robert McCoy and Jim Young (Holla Bend Cutoff Project); Charles Kelley and Walter Mims (Jackson Lock and Dam). In addition, the authors wish to acknowledge the contributions made by certain members of the U. S. Congress and State Legislatures, the U. S. Department of the Interior, U. S. Corps of Engineers, various state institutions, citizens groups, and others - many of whose names frequently appear in the long chain of communications associated with these projects.

The following professionals interviewed deserve special mention for their dedication and effort toward the success of conservation efforts in the Southeast: Charles E. Crowther, Lawrence S. Givens, Walter A. Gresh, Roland Handley, Charles H. Harris, Robert Lines, James P. McBroom, Robert Myers, Travis S. Roberts, Paul Smith, Spencer H. Smith, and William L. Towns (U. S. Fish and Wildlife Service Region 4, 1946-1970); Trusten H. Holder and Andrew H. Hulsey (State of Arkansas).

The authors also wish to thank Kenneth E. Black, Russell D. Earnest, Stephen W. Gard and their staffs (Division of Ecological Services, Region 4, FWS), and the managers and staffs of the National Wildlife Refuges, and Larry Green, BG Kenneth E. McIntyre, Colonel John H. Moellering, St. Clair Thompson and their staff (South Atlantic and Lower Mississippi Valley Division, U. S. Corps of Engineers) for cooperation and assistance with the conduct of our study.

Lower Snake River Fish and Wildlife Compensation[1]

L. Victor Armacost[2]

Abstract.--In 1945 multipurpose water resource projects were authorized on the Lower Snake River without adequate provision for fish and wildlife compensation. With the realization of the impacts, this compensation was authorized in 1976. This paper covers development of the plan and efforts to implement it.

THE RIVER

The Snake River heads on the western slopes of the Rockies in Wyoming and winds across Idaho through Hells Canyon where it forms the boundary between Idaho and Oregon, and flows on into Washington to Columbia River at the rapidly growing cities of Pasco, Kennewick, and Richland. The river provides fish and wildlife habitat, irrigation, energy, navigation, and boating. It is another 325 miles to the Pacific Ocean from the mouth of Snake River. This stretch of Columbia River is a series of slackwater reservoirs created by four dams. The first dam below the mouth of Snake River is McNary, which became operational in 1954.

The climate in the lower Snake River is hot and dry in summer with temperatures in excess of 100°F being common with mild winters and annual precipitation averaging less than 12 inches. The lower Snake River Canyon varies in depth from 100 feet near its mouth to 2,000 feet near Lewiston, Idaho.

LOWER SNAKE RIVER PROJECTS

In 1945 four multipurpose water resource projects were authorized for construction by the Corps of Engineers. (Fig. 1.) The major purpose of these projects was to provide electric power and complete the navigation link between the Pacific Ocean and Lewiston, Idaho. Construction began in 1958 at the Ice Harbor project and was essentially completed when power went on the line at Lower Granite in 1975. Each project has six turbines with the four project total generation capacity in excess of three million kilowatts. Each dam raises the water approximately 100 feet providing a slackwater pool to the next lock and dam, with a combined slackwater distance on Snake River from the mouth to Lewiston, Idaho, of about 140 miles. The amount of storage is small in relation to the flow, so no flood control is provided. Reservoir fluctuations are limited to a maximum of five feet.

While the 1945 project authorization did not provide for fish and wildlife compensation, fish passage features for both upstream and downstream migrants were incorporated into the dams and some project lands were made available for wildlife. More than $52 million was spent on facilities for anadromous fish passage in the original project construction.

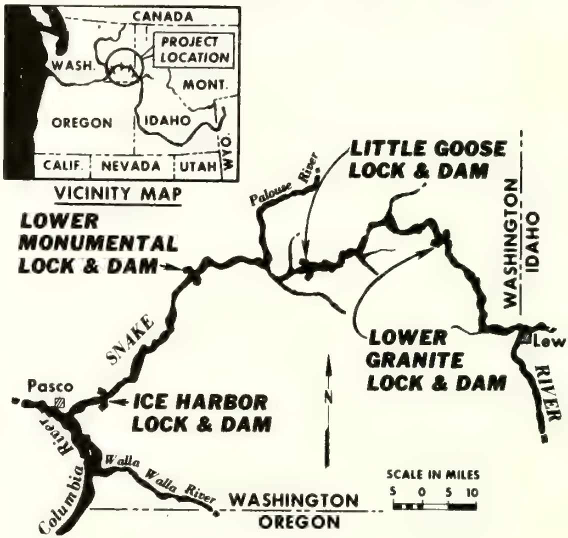


FIG. 1 LOWER SNAKE RIVER PROJECTS

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[1] Paper presented at the Mitigation Symposium, A National Workshop on Mitigating Losses of Fish and Wildlife Habitats at Colorado State University, Fort Collins, Colorado, July 17-19, 1979.

[2] Manager, Lower Snake River Fish and Wildlife Plan, U.S. Army Engineer District, Walla Walla, Washington 99362

PRE-PROJECT FISH AND WILDLIFE RESOURCES

Fish

The Snake River Basin is one of the most important fish-producing systems in this country. Anadromous fish from this system contribute substantially to the commercial and sport fisheries in the Columbia River and its tributaries and the Pacific Ocean from California to Alaska. However, prior to the completion of Ice Harbor Dam in 1962, it was impossible to get actual counts of migrating fish. Fish moving up the McNary fish ladders have been counted since 1954. To determine compensation requirements, it was accepted that the impacts of McNary and other projects built prior to 1954 required the maximum rather than average counts at McNary be used as a basis for the number of anadromous fish in Columbia River below Snake River and that the maximum ratio of Ice Harbor to McNary counts in the 1962-1967 period would be used to determine the numbers of fish entering Snake River. On this basis it was estimated that in the pre-project condition 37,700 fall chinook, 122,000 spring and summer chinook, and 115,000 steelhead moved into the lower Snake River annually. In addition, important species of resident fish, including small mouth bass, channel catfish, sturgeon, and whitefish, provided an intensive sport fishery in the project area that provided 250,000 angular days annually.

Wildlife

A variety of wildlife used the lower Snake River Canyon. Mule and white-tailed deer inhabited the canyon slopes and bottom lands. Fur bearers include beaver, muskrats, mink, raccoons, skunks, weasels, bobcats, river otters, badgers, and coyotes. Upland game birds include California quail, Chukar and Hungarian partridge, and ring-necked pheasant. Mourning doves were prevalent in the canyon. Thousands of ducks and geese wintered annually on embayments and islands. There was also a variety of non-game wildlife. Table 1 shows the wildlife population estimates made by the Washington State Department of Game.

PLAN DEVELOPMENT

The Fish and Wildlife Coordination Act of 1958 (PL 88-624) provided the basis for mitigating project impacts on fish and wildlife resources. The initial mitigation efforts started out on a project by project basis with U.S. Fish and Wildlife Service providing three separate reports covering Ice Harbor, Lower Monumental, and Little Goose projects. In general, these reports recommended fish passage, and providing small land and water areas and management funds to the Washington Department of Game for wildlife. However, the Little Goose report recommended fish propagation facilities which were questioned by the Walla Walla District of the Corps of Engineers (WWD). After exchange of letters concerning the Little Goose mitigation requirements, WWD, on 11 April 1966, requested a comprehensive report covering fish and wildlife losses for all four projects.

TABLE 1. Wildlife Populations in Project Area Pre-Project Conditions[1]

Species	Base No. Before Inundation
GAME	
Deer	1,800
Pheasant	22,000
Quail	56,900
Huns	19,800
Chukar	52,100
Doves	120,200
Cottontail	8,400
WATERFOWL[2]	
Ducks	17,500
Geese	2,200
FUR ANIMALS	
Beaver	1,100
Muskrat	26,900
Mink	2,300
Otter	200
Raccoon	2,600

[1] Determined from special survey of 1964-65-66 harvest in project areas, numbers rounded.

[2] Reflects hunting season population only-does not indicate production changes.

In early 1971, a first draft report was received from the Bureau of Sports Fisheries and Wildlife and after several meetings and additional draft reports, in mid-May 1973, WWD received directions to obtain independent consultants review and prepare an Environmental Impact Statement (EIS). Dr. Pengelly, Professor of Forestry and Wildlife at the University of Montana, was selected to review the wildlife portion of the plan and Dr. Ernest O. Salo, Professor, Fisheries Research Institute at the University of Washington, was hired to review the fisheries aspects. Both consultants essentially supported the mitigation levels developed by the wildlife agencies and provided their reports in the summer of 1974. In May 1975 a report entitled, "Special Report, Lower Snake River Fish and Wildlife Compensation Plan" was officially sent out of the Walla Walla District on its way to Congress and on 22 October 1976 the Lower Snake River Fish and Wildlife Compensation Plan was authorized. First funds to implement the plan were made available in October 1977.

IMPACT ON THE FISHERY

The major project impacts were the conversion of 140 miles of free flowing river to a reservoir-type habitat and the four substantial obstructions to fish movement. Possible anadromous fish losses include juveniles in turbines through both direct mortality and being stunned in passing through the turbine and over spillways so they are more susceptible to predation; increased juvenile predation because reservoirs are more conducive to predator production; delay in reaching the seas as a result of reservoir migration rather than a fast-flowing river; losses of adults in seeking, entering, and passing through the fishway system; losses of both adults and juveniles to nitrogen supersaturation; and loss of spawning grounds.

Of these potential losses the ones that were quantified and provide the basis for compensation were the loss of spawning grounds that were estimated to return 5,000 fall chinook and a 48 percent cumulative loss to juvenile downstream migrants passing through the project turbines. This results in compensation requirements to return 58,700 spring and summer chinook, 18,300 fall chinook, and 15,100 steelhead adults to the lower Snake River. In addition, it was estimated that 130,000 fisherman-days of sports fishing for anadromous fish were lost annually. Fishing studies in 1969 (Tri-State Steelheaders, Inc., Walla Walla, 1970) show that sports fishing for anadromous fish in the lower Snake River reservoir is nearly futile even when sonic togs are used to identify the fish routes through the reservoirs.

The residents sports fishery in the project area was also adversely impacted and 93,000 pounds of trout production or equivalent resident fish production for tributary streams is to be provided for compensation.

IMPACT ON WILDLIFE

The lower Snake River projects inundated 140 miles of riparian habitat and an additional 14,000 acres of bottom lands and canyon walls. These impoundments resulted in the loss of 48 islands five acres or larger in size, and 34 embayments five acres or larger in size. Only two islands of considerable size and six embayments were formed. Virtually all brushy shoreline, agricultural bottom land, and river island habitat have been lost. Railroad and roadway relocations have resulted in riprap embankments replacing much of the shoreline and creating hazards in gaining access to the water, particularly for larger forms of wildlife. Such bank protection measures also preclude reestablishment of vegetation that is vital to the survival of wildlife. Table 2 summarizes the impacts of the project on wildlife as estimated by the fish and wildlife agencies.

TABLE 2. Average Annual Wildlife User Losses

Group	Loss
Big Game	9,900 man-days
Upland Game	28,500 man-days
Waterfowl	1,000 man-days
Non-Game	3,100 acres
Fur Animals	2,100 pelts
Appreciative Use	43,500 man-days

COMPENSATION PLAN

The program to compensate the lower Snake River project-created Fish and Wildlife losses will cost more than 70 million dollars, most of which will be paid from power revenues generated by the project. The estimated benefit to cost ratio is approximately 3.

Fish

The fishery element of the plan will comprise more than 90 percent of the estimated compensation plan costs. The major part of the fish program involves the construction of hatcheries and supporting facilities. The fish program is based on the premise that fish should be returned to their natural spawning areas. This will require trucking from hatcheries for placement either directly into the streams or into acclimation ponds. Adult traps and spawning facilities with eggs transported to the hatcheries will also be required. There is also to be 750 acres of stream bank access for fishing to replace the 140 miles stream-type fishing in the project area.

One of the major supporting studies for the fish hatchery program was completed in late 1974 by the Columbia Basin Fisheries Technical Committee's Lower Snake River Hatchery Committee which included representatives from both U.S. Fish and Wildlife

Service and National Marine Fisheries Service and from the fishery agencies of Idaho, Oregon, and Washington. This committee determined fish species distribution by stream and the basic hatchery production requirements.

Either Fish and Wildlife Service (F&WS) or National Marine Fisheries Service (NMFS) are to budget for the hatchery operation with both agencies indicating desire to support the program. The appropriate state agency will be the actual operating entity except in cases where an existing Federally operated hatchery is being expanded. Hatchery design criteria will be largely provided by the operating agency, with design review opportunities provided to all fishery agencies of Idaho, Oregon, and Washington, NMFS and F&WS.

The Lower Snake River Hatchery Committee also identified eight potential hatchery sites; however, it now appears that only one of them will actually be satisfactory. This site is McCall, Idaho, Summer Chinook Hatchery which is currently under construction. This hatchery has been expedited because of the extremely low runs of summer chinook and the concern for their survival. The preliminary design of this hatchery was started in 1977 with funds provided through the Columbia River Fisheries Council to Idaho Fish and Game Department.

In addition to the McCall Hatchery design, an intensive fish hatchery site search was started in October 1977. The primary restraint in locating a hatchery is finding an adequate water supply of the right quality. Temperature is a particular restraint in the use of surface waters. Flow requirements will range from a minimum of approximately 20 cfs to flows approaching 100 cfs for anticipated large steelhead hatcheries. The data collection program has included 20 thermograph installations with accompanying water quality sampling at most sites, drilling of 18 exploration wells, and numerous stream flow measurements, as well as reviews of existing water supply and quality information.

So far, fish hatchery sites have been identified for rearing the total summer chinook requirement, 17 percent of the spring chinook, and 35 percent of the steelhead. Current explorations indicate there is a good possibility sites have been identified for rearing all of fall chinook and another 25 percent of the steelhead with site studies continuing to assure that the compensation requirement will be met. One fish hatchery is under design in each of the three affected states.

A site for the hatchery to provide the required 93,000 pounds of trout has also been located. However, initial construction will be for a facility to produce only 45,000 pounds of trout while we await results of a study to determine the feasibility of improving stream habitat to get increased natural production and another study to determine the feasibility of increasing warm water fish in the reservoirs of the lower Snake River projects.

Lands for streambank fishing access have been identified in Washington where 700 of the 750 acres are to be located. WDG has identified all the suitable stream reaches on tributaries to Snake River in Eastern Washington. As the workshops (which are discussed in the Wildlife Section) indicate it will probably be impossible to obtain sufficient lands in these tributaries, they are now identifying additional areas on other streams. The other fifty acres are to be located in Idaho and specific stream reaches have not been identified.

Wildlife

Wildlife Compensation is to be accomplished by developments on existing project lands and by the acquisition of additional lands. The on-project development will include approximately 1,000 acres of irrigated plantings for optimal wildlife habitat plus fencing of trees and shrubs, meadows, pastures, fields, annual food plot, guzzler complexes, and nest structures for both geese and cavity nesters (Holzwarth 1979). The development of the on-project concepts would provide an interesting and informative report by itself; however, it will not be discussed further here.

The off-project wildlife requirements that were developed to meet wildlife compensation are all to be located in Washington and are 15,000 acres of range land in the canyon adjacent to project land for chukar partridge hunting; 8,000 acres of hunting easements on farm land surrounding 400 acres of wildlife habitat to be purchased in fee primarily for pheasant and quail; and 20,000 game birds per year for 20 years to provide hunting opportunities while natural habitat is developing. All wildlife lands are to be obtained on a willing-seller, willing-buyer basis. The 8,400 acres of pheasant and quail land cannot be purchased without approval of the various County Planning Commissions. The Plan also requires that within five years after first receipt of funds, by October 1982, the Corps is to report on the success of its acquisition progress. All easements are to be perpetual easements.

As it was known that many local landowners were opposed to the program, a very deliberate approach was taken in identifying compensation lands. Washington Department of Game (WDG) developed criteria for selection, development, management, planning coordination and monitoring success of management units and from this criteria proceeded to identify lands that were suitable for compensation. Using this information, meetings were held with County Commissioners in each of the five counties to explain the compensation plan and the proposed workshops. The workshops were arranged so that people could come anytime between 2:00 and 9:00 p.m. and have the program explained.

In Columbia County, Washington, the County Commissioners objected to this type of meeting and scheduled a planning commission meeting in which the Corps and WDG explained the program. All people who spoke at this meeting were opposed to the wildlife program. The Planning Commission then declared that the compensation plan was incompatible with their comprehensive plan and subsequently the Columbia County Commissioners requested that a workshop not be held in that county.

These workshop meetings were held in the four other counties in early May 1979. In one of the counties, Whitman, where a significant portion of the potential upland game bird land is located, the Planning Commission also declared the compensation plan was in conflict with their comprehensive plan and the County Commissioners subsequently asked that a meeting be held with the Planning Commission to review the plan.

Most of the attendees at the workshops were opposed to the Wildlife Compensation Plan; however, significant numbers of landowners of potential wildlife land did not attend the workshops. The opposition to the plan was the same as expressed in the 1973 public meetings and include:

- Belief that wildlife losses did not really occur.
- Resentment of additional Government taking of land.
- Concern about management ranging from inadequate weed control to uncontrolled vandalism.
- Concern about selling hunter rights for perpetuity.

It should also be noted that many of the people whose lands are suitable for wildlife compensation had lands that were taken for developing the Lower Snake River projects and in this process had developed animosity toward the Corps.

The 20,000 game birds per year for 20 years to stock both project and off-project lands were to be provided by the Washington State Department of Game for a lump sum payment of $1,159,000, the estimated capitalized value. Recently WSG has expressed concern about making a long-term commitment to game bird production and is reconsidering their commitment to this production.

Idaho Department of Fish and Game is claiming there should also be off-project wildlife lands provided in Idaho. A consultant was hired to review the project-caused impacts in Idaho and generally concluded that adequate data were not available to make a completely definitive analysis, but it appeared that on-project measures would adequately compensate for wildlife losses.

SOME OBSERVATIONS

General

* The Compensation Plan implementation is going forward as a cooperative effort of the Oregon, Washington, and Idaho Fish and Game agencies, Fish and Wildlife Service, National Marine Fisheries Service, and Corps of Engineers.

* The fishery resource in particular has suffered because of the long delay in implementing compensation measures.

* While fishery compensation has little opposition and both public and agency support, the wildlife program has major opposition and very little visible public support.

* Determining if mitigation is being accomplished by the compensation program is probably impossible unless it fails miserably. For example, the numbers of anadramous fish returning from the ocean are dependent upon natural biological factors, fishery management in both the ocean and the river system downstream of the project area. Further, at the present time there are no objective measures to determine when suitable quality smolts are being released. Wildlife also has natural biological cycles and is subject to human factors ranging from variations in hunting pressure to changes in land use.

Fish

* Finding sufficient water supplies for large hatcheries operated without recycling flows is proving to be difficult. If additional major hatchery programs are to be accomplished in the northwestern United States, research on fish rearing facilities that use significantly less water than current design is needed.

* The variation in hatchery design criteria between states, the limited amount of dependable data on flows, fish growth and other pertinent information from existing facilities all suggest that a scientific based system effort to develop hatchery design criteria is needed.

* A small change in the ratio of returning adults to released smolts will change hatchery rearing requirements substantially; for example, a change of 0.1 percent in this ratio will change hatchery rearing requirements by about 20 percent.

Wildlife

* As a substantial amount of hunting takes place on private land, it is necessary to avoid antagonizing landowners with the wildlife compensation program to avoid losing existing hunting opportunities.

* Basic appraisal information on hunting easements is scarce which will make it difficult to determine fair market value for these easements.

* The fact that the Government purchasing procedures provide for one lump sum payment and subsequently a large tax burden on the seller makes acquisition even more difficult.

* The effort to show the landowners we were reacting to their concerns by developing management and acquisition programs that took into account such things as vandalism, weed control, and control of access points was a failure. The same opposition presented in 1973 was heard again in May 1979.

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Wildlife Mitigations at Bureau of Reclamation Projects: A Case Study Approach[1]

Judy A. Voigt[2] Julius G. Nagy[3]

Abstract.--Project impacts and mitigation success were studied at 10 Bureau of Reclamation developments. Improvement of the mitigation process should concentrate on: 1) increasing funding for wildlife; 2) increasing communication between agencies; 3) concurrent mitigation and project development; and 4) effective early planning and post-development study.

INTRODUCTION

Energy developments in the U.S. involving renewable resources have increased substantially in recent years. In response, concern for mitigating resultant impacts has also increased. Effectiveness of mitigating fish and wildlife losses has been limited (Houck 1978). Therefore, further study and understanding of previous and ongoing attempts to plan and implement mitigation is essential. By evaluating water developments, in particular, increased understanding of successful mitigation procedures can assist in improving mitigation effectiveness at other forms of energy development.

The objectives of this research were to:

1. review recent legislation and policy to evaluate their effects on mitigation success;
2. delineate actual impacts to wildlife and the extent to which they were mitigated;
3. determine which steps of mitigation development were completed on each of 10 selected water projects, and the success of implemented measures; and
4. identify, where possible, reasons for successful mitigations.

BACKGROUND

One of the first legislative measures directly concerned with the need to lessen fish and wildlife losses at water resource developments was the 1958 Fish and Wildlife Coordination Act (FWCA) (16 U.S.C. 661 et seq.). According to the Act, fish and wildlife resources must be considered equally with other features of water resource development at federal or federally assisted water projects. Consultation between the U.S. Fish and Wildlife Service (USFWS) and the construction agency involved was to occur, providing measures for preventing loss of and damage to fish, wildlife, and their habitats.

The FWCA, however, did not provide the necessary alleviation of fish and wildlife losses its authors originally intended. Attempts to increase this consideration for wildlife have been made through subsequent legislative and policy measures, most important of which was the 1969 National Environmental Policy Act (NEPA) (42 U.S.C. 4321 et seq.). NEPA required preparation of an environmental impact statement (including measures for mitigating environmental losses) for all major federal actions significantly affecting the quality of the human environment (Sec. 4332(c).).

Another measure affecting mitigation for wildlife losses was the 1973 Principles and Standards for Planning Water and Related Land Resources (Fed. Reg. 38(174):24795-24869). Their overall purpose was to promote the quality of life; national economic development and environmental quality were to be considered equal objectives in water resource planning.

The 1973 Endangered Species Act (16 U.S.C. 1531 et seq., as amended by P.L. 95-632, Nov. 10, 1978) also affected wildlife mitigations. If the critical habitat of an endangered species was executively exempted from the mandates of Section 7, mitigation implementation was required. Three additional measures which included considerations for fish and wildlife at natural resource developments were the Surface Mining Control and Reclamation Act (1977), the Bureau of Land Management Organic Act (1976), and the National Forest Management Act (1976).

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[1] Paper presented at The Mitigation Symposium, Fort Collins, Colo. July 16-20, 1979.

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METHODS

The case study approach was chosen for this evaluation as a means of pinpointing successful and unsuccessful procedures in mitigating wildlife losses. Ten Bureau of Reclamation projects were studied (Fig. 1) based on the following criteria:

1. time of authorization and extent of completion differed between project sites;
2. big game were adversely affected;
3. projects were included under the 1958 FWCA;
4. information on project impacts and recommended and implemented mitigation was available; and
5. projects were located in western states, where inferences could be made to future energy developments (including coal and oil shale).

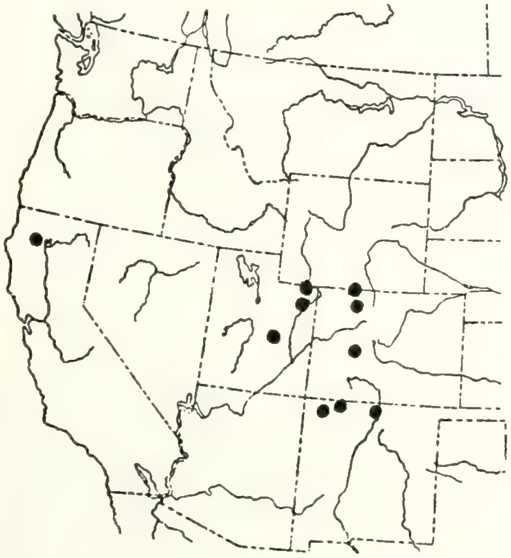

Figure 1.--Locations of the 10 water projects studied during case research, 1978-1979.

In order to determine suitable mitigatory measures in the future, factors inherent in alleviating losses associated with energy developments must be identified and analyzed. Therefore, evaluation of each project included: 1) legislative and regulative requirements; 2) predicted and actual impacts on wildlife; 3) mitigation recommendations; 4) decision-making processes; 5) extent and success of implemented mitigations; and 6) specific areas of disagreement and cooperation in mitigation planning, implementation, and follow-up.

Sources of information for this evaluation included authorizing and other pertinent legislation, USFWS and Bureau of Reclamation reports to Congress, and inter- and intra-agency memoranda. Communications with knowledgeable persons in federal and state wildlife and construction agencies and at project sites also provided valuable sources for acquiring information.

RESULTS AND DISCUSSION

Results of this evaluation have been categorized into 10 issue areas as follows: 1) defining mitigation; 2) evaluative criteria; 3) early planning; 4) implementation; 5) operation and maintenance; 6) follow-up; 7) funding; 8) "retrofit" of mitigation to already authorized or constructed projects; 9) areas of disagreement and cooperation; and 10) third party involvement. Issues 3 through 6 constitute the process of mitigation. The final two issues are general categories, inherent throughout both project and mitigation development.

Defining Mitigation

In order to suitably develop, fund, and implement wildlife mitigation measures at energy developments, a definition of "mitigation" must be consistent between all agencies involved. The Savery-Pot Hook Project, planned for development on the Colorado-Wyoming border, provided one example of the need for establishing a more complete understanding and acceptance of this term. "Mitigation" was not used by the USFWS (1976) in their report on fish and wildlife resources. Instead, the terms "offsetting" (adverse impacts, p.31), "preventing" (losses, p.34), and "partially compensating" (losses by increasing the carrying capacity of adjacent habitats, p.33) were used.

Evaluative Criteria

Problems in determining appropriate mitigative measures have stemmed from inaccurately predicting the amount and significance of impacts on any wildlife resource due to project development. One example of this was the

Trinity River Division of the Central Valley Project, north-central California (completed in 1963). Baseline studies of wildlife could not adequately determine the pre-impoundment value of the area's black-tailed deer. An influx of deer into the newly cleared reservoir site just prior to impoundment resulted in an overestimation of actual animal abundance in the immediate area. Consequently, neither the full impact of construction on the herd nor the effectiveness of mitigation measures at the Trinity development could be known. Deer numbers could not be compared because of incommensurable pre- and post-development resource assessment methods (Trinity River Basin Fish and Wildlife Task Force 1975).

Early Planning

It was evident throughout case study that in order to smoothly and effectively implement appropriate mitigative measures, early planning was essential. Five factors affecting the outcome of early mitigation planning were identified: 1) concurrent mitigation and project development; 2) inter-agency cooperation during early planning stages; 3) adequate funding and personnel to carry out wildlife studies as well as other facets of project planning; 4) consideration of biological constraints in choosing appropriate mitigative measures; and 5) political influences.

One example of poor interagency coordination during early planning occurred with Blue Mesa, located on the Gunnison River in west-central Colorado (completed in 1966). The Gunnison River was one of the nation's finest trout streams, and the valley provided critical big game winter range (U.S. House of Representatives 1978:30). Initial mitigation planning procedures mandated by the FWCA were never completed with this development. The USFWS opposed project construction throughout the planning stages, due to the unmitigability of both fish and wildlife losses. Therefore, mitigation recommendations were never agreed upon by the agencies involved (USFWS, Bureau of Land Management, and U.S. Forest Service), and a mitigation plan was not submitted to the Bureau of Reclamation by the USFWS until 1978. Hence, mitigation to date has been extremely limited at Blue Mesa. Land acquisition to mitigate fishery losses occurred, but only one parcel of land (1770 ha) has been acquired for big game management (personal communication Steve McCall, Bureau of Reclamation).

Implementation

Implementation of appropriate mitigative measures can proceed smoothly only if mitigation is well planned early in project development. Case research, however, showed that effective early planning leading to implementatio has been difficult to achieve. Funding availability and coordination with land availability were the primary factors limiting implementatio of mitigating measures. Interagency cooperatio and public acceptance of mitigatory procedures also played a part in effective implementation. In addition, the suitability of mitigation to habitat and wildlife needs (physical and biological factors) was limiting, and political influences in carrying out mitigation often affected the timing and actual extent of implementation.

Political influences were apparent in implementing mitigations at Flaming Gorge, southwest Wyoming and northeast Utah. Pinyon-junipe chaining and reseeding on state and Bureau of Land Management lands began in 1964, shortly after project completion. As of 1973, 1750 ha were manipulated and grass re-establishment was good. Habitat management was cut short, however, when the Bureau of Land Management became apprehensive over the use of chaining as a management tool. Consequently, winter range rehabilitation at Flaming Gorge was effectively reduced.[4]

Operation and Maintenance

After instituting mitigation, operating and maintaining those measures may be as crucial to mitigation success as the actual implementation (U.S. House of Representatives 1978:303-321). The need for both biological and structural maintenance of many features designed to lessen fish and wildlife losses was apparent through case research.

To mitigate big game losses resulting from Trinity River Division, pinyon-juniper was chained and seeded. But seed catch and survival were poor, and no attempts were made to reseed (Trinity River Basin Fish and Wildlife Task Force 1975). As a result, the effectiveness of this mitigation attempt at Trinity was limited.

Follow-up

In order to document the success of implemented measures and identify areas for further mitigations where necessary, there must be monitoring during and follow-up after implementation. As a result of case analyses for this report, follow-up study was found to be extremely valuable in evaluating mitigation success. Existence and effectiveness of completed follow-up studies were largely due to three factors: 1) availability of funding and personnel to conduct studies; 2) use of consistent and uniform evaluative criteria in collecting baseline data and assessing relative post-construction mitigation effectiveness; and 3) political support.

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[4] N.V. Hancock. 31 March 1975. Memorandum to J.R. Udy, Dir. Utah Div. Wildl. Resour. Subject: Report on Section 8 wildlife needs at Flaming Gorge Unit. On file at Utah Div. Wildl. Resour., Salt Lake City.

One example of follow-up associated with fishery resources occurred at the Flaming Gorge impoundment. Bureau of Reclamation personnel were alerted to drastic changes in water temperatures leaving the dam through the original outlet structures (penstocks). Reservoir stratification a few years after construction resulted in a layer of extremely cold water at outlet levels, adversely affecting the trout fishery in the Green River downstream. Also, a pool of stagnant water had formed in the reservoir, and its escape would adversely affect indigenous aquatic flora and fauna. As a result of follow-up, then, nearly $4 million in mitigation funding (from Section 8 of the Colorado River Storage Project Act) was appropriated in Fiscal Year 1977, and penstocks were extended to higher, warmer water levels (Sersland 1977).

Funding

As shown by case research, timely funding was necessary to complete all four stages of mitigation: early planning, implementation, operation and maintenance, and follow-up. When mitigating wildlife losses, political influences often determined the allocation of needed funds. Factors limiting effective authorization and appropriations included: 1) availability and timing of funding; 2) source of funding; 3) funding as a project cost (benefit/cost ratios of project development may be lowered when funds for fish and wildlife mitigations are included as a project cost); and 4) agency cost ceilings.

According to Sersland (1977), a backlog of $50 million of Colorado River Storage Project mitigation recommendations were incorporated into project plans, but had yet to be implemented because of lack of funding. For example, at the Sam Juan-Chama Project, north-central New Mexico and south-central Colorado, monies to acquire land for big game ($1.56 million) were requested since 1963--concurrent with project construction. By 1975, land prices in the area had tripled. Finally, New Mexico Governor J. Apodaca became involved in San Juan-Chama land acquisition, Colorado River Storage Project Act Section 8 mitigation monies were appropriated for Fiscal Year 1977, and 3150 ha were acquired for big game management (U.S. House of Representatives 1978:648-659).

Retrofit

The effects of water resource developments differ among habitats and over time. Therefore, a mitigation "package" must be tailored to best alleviate specific impacts where mitigation implementation has been nonexistent or incomplete on authorized, partially developed, or already constructed projects. This concept is referred to as "retrofit" (personal communication Ann Rappoport, USFWS).

At Blue Mesa, for example, lack of a mitigation plan at the time of project authorization limited land acquisition possibilities for big game. Increases in secondary developments in the immediate project area, and decreased purchasing power of authorized funds over time, had interfered with implementing mitigations. Moreover, the time consuming process of early planning, inter-agency coordination, recommendation, authorization, and appropriation for mitigatory measures had to occur after construction began--and before any mitigation was possible.

Areas of Disagreement and Cooperation

Case research revealed three areas (intra- and inter-agency, and public) where the cooperation or disagreement between involved groups was most critical to mitigation development. Inter-agency disagreements, for example, could result from differences in the education and experience of decision-makers, as well as in the goals of each involved agency regarding project development. Cooperation between agencies was of primary importance in successfully mitigating impacts. Communication breakdowns, however, typically characterized projects where increasing inter-agency understanding was essential to effectively lessen adverse project effects.

One example of public involvement in mitigation decision-making occurred with the Savery-Pot Hook Project. Public discontent with the Draft Environmental Statement became apparent at a public hearing on proposed mitigation measures (October 25, 1975). Consequently, mitigation recommendations were altered, resulting in a program less disruptive to local landowners (U.S. Bureau of Reclamation 1976).

Third Party Involvement

Individuals or agencies not directly involved in mitigation decision-making at specific developments are third parties. Third party attempts to influence mitigation choices, positively or negatively, occurred throughout the four stages of mitigation development. As revealed by case research, third parties included political leaders, private individuals or organizations, and individuals within already involved public agencies.

One case study exemplifying the effects of third party involvement was the Navajo Indian Irrigation Project, northwest New Mexico. When the USFWS became concerned over big game drownings in the project's irrigation canal, the ex-governor of the state of New Mexico and New Mexico Senator P. Domenici became involved in attempts to alleviate those losses. The Senator wrote to the Secretary of the Interior requesting funding for big game studies along the canal to document actual losses.[5] Subsequently, funding became available, and studies are ongoing.

CONCLUSIONS

Areas for improving the mitigation process became apparent through case research. Availability of funding, and communication--especially between agencies, most often determine mitigation success. A uniform definition of "mitigation" is necessary before improvements can be made to increase the effectiveness of implementation. Habitat-based impact assessments must replace monetary-based ones in order to uniformly determine effective mitigation recommendations. Follow-up study must be undertaken to document mitigation success.

Recent developments provide means for increasing mitigation effectiveness, especially at water projects. The President's Water Policy Directives of June 1978[6] required, for example, that mitigation funding and implementation be provided concurrently with project appropriation and construction, and that the Department of Interior promulgate regulations for implementing the FWCA. Regulations have been proposed (Fed. Reg. 44(98): 29299-29359). They provide the opportunity for increased follow-up study, and for appropriately designed post-operative mitigation when attempts have been nonexistent or unsuccessful. Administration and amendment of the FWCA was the subject of 1978 Hearings before the Subcommittee on Fisheries and Wildlife Conservation and the Environment (U.S. House of Representatives 1978). And the USFWS is currently revising their Habitat Evaluation Procedures for assessing environmental impact.

These steps for increasing mitigation efficacy at water projects can be expanded to include other energy developments adversely affecting natural resources. But regulations must be adhered to, Congressional amendment must occur when necessary, wildlife agencies must actively pursue adequate funding, and there must be a heightened awareness of the need to lessen wildlife losses. Development and natural resource agencies and organizations and the public must assume responsibility for assuring the presence of diverse and abundant wildlife resources for the future, especially in the face of increasing energy developments.

ACKNOWLEDGEMENTS

The authors are indebted to Ann Rappoport for her assistance throughout case research and in editing. J. Haufler, D. Hein, S. McCall, M. Rowland, D. Smith, and L. Stelter reviewed the manuscript. This research was made possible by the USFWS, Office of Biological Services, Contract No. 14-16-0008-2016.

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Unmet Mitigation in the Lower Mississippi River and Tributaries[1]

Stephen W. Gard[2]

Abstract.--Of the 25 million acres of forested wetlands in existance just 50 years ago in the Lower Mississippi River Valley, approximately 3 million acres remain, and these are being drained and cleared at the rate of about 300,000 acres per year. These bottomland hardwood wetlands are considered one of the most biologically productive habitat types in North America. The ability of the wetlands to produce both variety and number of animals, their value to wintering waterfowl, and the fact that a great threat exists to the remaining acreage makes this habitat even more important to the Nation and its wildlife resource heritage.

Since much of this loss can be attributed to Corps of Engineers (CE) flood control and navigation projects and to land use changes in expectation of such projects, a study has been undertaken of all CE projects in the Lower Mississippi River Valley and tributaries from Cairo, Illinois, to the Gulf of Mexico which had major Fish and Wildlife Service (FWS) mitigation recommendations. Tributaries to the west of the Mississippi River were studied only to the Texas and Oklahoma state lines.

As part of the FWS study of these water resources projects under the Fish and Wildlife Coordination Act, the Service has recommended on 39 projects 610,740 acres of mitigation lands to partially compensate for the loss of over 2,000,000 acres of forested wetlands. Of the 610,740 acres, 182,765 acres or 18 percent of the recommended lands have been authorized, but only 36,683 or 6 percent are in place and under management at this time. This leaves an unmet mitigation deficit of 574,057 acres.

The major reasons for this unmet mitigation were lack of public support, CE resistance to the mitigation concept, lack of State support, and FWS ineffectiveness.

INTRODUCTION

This is a study of all U.S. Department of the Army, Corps of Engineers' (CE) projects in the Lower Mississippi River Valley in which the U.S. Fish and Wildlife Service (FWS) has made significant mitigation recommendations. Our purpose is not only to study existing history and point out the extensive unmet mitigation, but to also make a general assessment of fish and wildlife resource losses and explain in light of present laws what has happened and why.

The project study area includes all of the Lower Mississippi River Basin and tributaries from Cairo, Illinois, to the Gulf of Mexico. All Mississippi River tributaries were studied in Mississippi, Tennessee, Kentucky, and that part of Missouri south of Cairo, Illinois. In Arkansas and Louisiana, the tributaries were only studied to the Texas and Oklahoma state lines.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, CO, July 16-20, 1979.

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For the purpose of this report, the term "mitigation" shall mean those significant structural features or land acquisition requests made by the FWS to offset identified fish and wildlife resource losses or identified adverse impacts. The term "unmet mitigation" shall mean those structural or land acquisition requests made by the FWS, but not in place at this time. Projects authorized for planning only, or presently inactive, or mitigation requests of less than two years old were not considered as unmet mitigation. Minor modifications such as seeding spoil banks, using only single bank construction, etc., were not considered significant enough for inclusion in this report.

FWS MANDATES

The FWS gained a significant role in the protection of fish and wildlife resources through the 1958 Fish and Wildlife Coordination Act amendments. The Fish and Wildlife Coordination Act provides for the recognition of the importance of fish and wildlife resources to the nation and provides that fish and wildlife conservation measures shall receive equal consideration and coordination in planning and implementing water resources development programs. Under this law, Federal agencies are required to consult with the FWS and appropriate State wildlife resource agencies whenever any stream or body of water is proposed or authorized to be impounded, diverted, deepened or modified for any purpose. Through this consultation the FWS is authorized to prepare reports and recommendations for the purpose of determining the possible damages to fish and wildlife resources and to determine means and measures to prevent (mitigate) the loss or adverse impact to the resources. The law also provides authorization for the construction agency to modify their plans to provide structural and non-structural measures as an integral part of the plan at project cost. The structural and non-structural features requested by the FWS are the mitigation features being considered in this study.

In addition to the Fish and Wildlife Coordination Act, the Service is guided by the provisions of the National Environmental Policy Act of 1969, the Executive Order 11988, May 24, 1977, on Floodplain Management, and the Executive Order 11990, May 24, 1977, on Protection of Wetlands.

The National Environmental Policy Act directs Federal agencies through a systematic, interdisciplinary approach to insure that presently unqualified environmental amenities and values be given appropriate consideration in decision making along with economic and technical consideration.

Executive Order 11988, Floodplain Management, describes the natural and beneficial value of floodplains and requires that Federal agencie "minimize potential harm . . . " to these values

The President's Executive Order 11990, Protection of Wetlands, states that each Federal agency "shall take action to minimize the destruction, loss or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands in carrying out the agency's responsibilities . . .". Executive Order 11990 further states that "each agency, to the extent permitted by law, shall avoid undertaking or providing assistance for new construction located in wetlands unless the head of the agency finds (1) that there is no practicable alternative to such construction, and (2) that the proposed action includes all practicable measures to minimize harm to wetlands which may result from such use."

THE PROBLEM

The Mississippi River Alluvial Floodplain once contained a vast complex of lush bottomland forests, overflow lakes, and bayous extending from southern Missouri to southern Louisiana. This area supported perhaps the most diverse and productive assemblage of fish and wildlife resources in North America. The magnitude of destruction of these forested wetlands during the past few decades has been staggering. Of the 25 million acres of forested wetlands existing just 50 years ago, approximately 3 million acres remain, and these are being cleared at the rate of up to 300,000 acres a year. These alarming losses can be largely attributed to federally-supported flood control and drainage projects an private agricultural development efforts.

Federal legislation in 1928 led to the development of the Mississippi River and Tributaries Project, the first major step toward massive federally-supported flood control in the region. Large-scale channelization, drainage, and levee construction projects allowed landowners to farm areas that had previously been too wet. The result was the conversion of about 22 million acres of valuable wooded wetlands to crop production. The remaining wooded wetlands in the Lower Mississippi Alluvial Floodplain have, accordingly, become much more important to the perpetuation of this habitat type.

The bottomland hardwoods of the lower Mississippi River valley are the major wintering area for mallards in the U.S. and support tremendous resident wood duck production. During the 1972-1976 midwinter surveys, mallard populations in the study area averaged about 1,700,000 and other ducks averaged approximately 542,000. The inventories also show that an average of at least 24 percent of the U.S. population and 58 percent of the Mississippi Flyway mallard population winter in the study area. Although population data are not available for wood ducks, the study area probably exceeds any similar sized area in both breeding and wintering populations.

The bottomland hardwoods are just as significant for furbearers, game species and other nongame species. Carrying capacities for deer and turkey are as high as one per 20 acres and one per 75 acres in this type habitat respectively. Furbearers such as oppossum, beaver, bobcat, otter, and raccoon are abundant in these areas and provide a significant commercial harvest. A density of 3.5 nesting pairs of songbirds per acre is not uncommon in bottomland hardwoods.

Besides the tremendous loss of wildlife species as a result of clearing and draining, the fisheries have suffered a similar loss. Population averages by the Louisiana Wildlife and Fisheries Commission have shown as many as 972 pounds per acre and a normal standing crop of 400-600 pounds per acre in backwater areas. These bottomland hardwood areas provide feeding, nesting, and breeding areas when the normal flooding regime exists. As the backwater flooding is reduced or eliminated through flood control, the ability of these areas to support fish populations is tremendously reduced or eliminated.

Then, as man converts these areas to other uses, primarily agricultural through clearing and draining, the loss of migratory waterfowl and resident species continues. This significant loss, if sustained at the present level, will eventually result in a total loss of bottomland hardwoods and the associated wildlife and fisheries resources, except for the few small areas in public ownership.

The area where forest land conversion to cropland has been most severe is the alluvial region (delta) of Arkansas, Louisiana, Mississippi, and Missouri. This drastic change in land use is primarily the result of the tremendous increase in worldwide demand for soybeans. Soybean acreage in the U.S. has increased by 65 percent since 1965.

The destruction of forested wetlands in the Arkansas portion of the delta has reached catastrophic proportions. In 1940, this figure had been reduced to an estimated 1.4 million acres. Of all Arkansas delta woodlands cleared during the past decade, approximately 90 percent were cleared for soybean production. Unless definite and aggressive action is taken to curtail this trend, practically every privately-owned wooded acre in eastern Arkansas will be cleared.

The soybean boom also brought land speculators and large farming corporations into the north Louisiana delta area. Massive land clearing operations were undertaken and large contiguous tracts ranging up to 50,000 acres were cleared and planted in soybeans. Many of these wooded tracts were converted to marginal cropland that was frequently flooded. Between 1962 and 1968, forested wetlands were cleared at a rate of over 111,000 acres per year. By 1969, land clearing operations had reduced this delta woodland acreage to about 2.5 million acres or 45 percent of its original size. If the present rate of land clearing continues, the forested wetlands of the north Louisiana delta will be eliminated by 1991.

The delta area in Mississippi has been the most dramatically altered in the three state region. The rich overflow bottomland in western Mississippi once contained an estimated 4 million acres of forested wetlands. This figure had been reduced by 60 percent between 1970 and 1976. It is estimated that less than 500,000 acres of forested wetlands still exist in the Mississippi delta. Publicly owned woodlands in that area total about 110,000 acres, and it is estimated that only this remnant of a once vast overflow forest will remain by the year 2000.

In Kentucky, Missouri, and Tennessee, the conversion has been just as significant but on a much smaller scale due to a smaller resource base.

Since the majority of this conversion of forested wetlands to farmland has been made possible by massive Federal flood control projects, the FWS has reviewed and made recommendations for offsetting some of the resource loss. Under the authority of the Fish and Wildlife Coordination Act, the FWS has recommended acquisition of 610,740 acres of forest land as mitigation for the loss of over 2,300,000 acres of wildlife habitat caused by Corps of Engineers navigation and flood control projects. These losses occurred primarily in the delta region of Arkansas, Louisiana, and Mississippi. Congress has authorized the acquisition of 182,765 acres of mitigation land, but only 36,683 acres have actually been purchased and placed in management.

Had the study taken into account those Corps of Engineers' projects where no mitigation was requested, such as the massive Mississippi River levee system, or if it were possible to quantify the cumulative impact of past flood control projects as influenced by the speculative anticipation of future flood control features and resultant forest clearing activities, the habitat loss figure would be many times greater than the presently attributed 2,300,000 figure. In addition, tremendous acreages have been cleared as a result of flood control activities of the Soil Conservation Service, State, and private interest.

The problem is that fish and wildlife resources have consistently received insufficient consideration in Federal flood control projects. Using the criteria developed for this study, there presently is an unmet mitigation deficit of 574,057.

UNMET MITIGATION

Within the study area, 58 Corps of Engineers' projects were found to have significant recommendations. Of the 58 projects, 50 were either authorized for or under construction, 4 were authorized for construction but inactive at this time and 4 were in planning. Of the 50 authorized or under construction, a total of 39 requests amounting to 610,740 acres of mitigation land have been recommended by the FWS under the Fish and Wildlife Coordination Act. Of this 610,740 acres, 182,765 or 18 percent of the recommended lands have been authorized, but only 36,683 acres or 6 percent of the recommended land is actually acquired and under management for fish and wildlife purposes at this time.

This leaves a total unmet mitigation of 574,057 acres and 35 structural requests. When these 50 projects are completed, the FWS has estimated there will be a direct and induced loss of 2,058,977 acres of bottomland hardwood habitat and channelization or modification of 6,657 miles of stream habitat.

The following table summarizes the request and damages by study area.

If one assumes that the 4 inactive and 4 projects in the planning stage are completed, the acres of compensation requested will be more than 642,806 acres with bottomland hardwood losses of over 2,324,786 acres and 7,692 miles of channelization or stream modification.

OBSERVATIONS

Having reviewed and compiled the data for this study, the question as to why such a tremendous mitigation deficit ever happened arouses a great curiosity. During the review, several factors became very evident from which one could make some valid assumptions concerning the reasons for the failure. They are listed in order of priority.

A. Public Support - In most cases there was an obvious lack of public support or lack of public awareness and understanding of what was being proposed. In many cases a strong anti-federal attitude and associated direct opposition to mitigation land acquisition proposals was evident from the very sportsmen who would logically be viewed as the ones who should be most supportive. The reason for opposition was generally because acquisition was viewed by members of private hunting and fishing clubs as a threat to their own best interest in that acquisition would lead to the establishment of a "preserve" or "refuge" where public use would be severely curtailed. The limited use frequently available on National Wildlife Refuges was generally confused with the type of management and use which would result on a State administered mitigation area.

A major cause for the persistence of this unfortunate situation would appear to rest on the shoulders of the agencies involved, particularly the FWS. The low key approach to the overall Fish and Wildlife Coordination Act effort, generally exhibited by both Federal and State agencies, allowed public confusion to

TOTAL FOR STUDY AREA

Projects Authorized for or Under Construction	Acres of Mitigation Land Requested/ Authorized	Acres in Place/ % of total acres in place	Number of Request Implemented/%	Acres of habitat lost/ Miles of channelization (upon completion)
(Active) 50	610,740 acres/ 182,765 acres	36,683 acres/ 6% of requested 18% of authorized	(Structural) 8 of 43/19% (Non-structural) 3 of 39/8%	2,058,977 acres/ 6,657 miles
(Inactive) 4	20,610 acres/ 0 acres	N.A.	N.A.	219,000 acres/ 692 miles
Projects authorized for planning only 4	11,456 acres/ N.A.	N.A.	N.A.	46,809 acres/ 343 miles

revail. Few efforts seem to have been taken to
lucate the public concerning the facts concern-
ng mitigation requests and the concept in gen-
ral. In terms of fully advising the public of
he seriousness of the pending impact upon fish
nd wildlife resources, it would seem that had
ll agencies involved in the planning efforts
onfronted the public with the facts of antici-
ated clearing trends even those members of pri-
ate hunting and fishing clubs would have recog-
ized the merits associated with the recommen-
ations.

In the few cases where public support did
evelop, some progress in obtaining authorization
mitigation measures was the result. Generally,
pport in these instances had as a catalyst the
enefits which the mitigation recommendation
uld accrue to the interest of project sponsors.
equally prevalent component of successful
forts was oftentimes the presence of local
ganized opposition or support to the project
d the resultant controversy. In response to
ntroversy and high visibility efforts to ad-
ess adverse fish and wildlife problems seemed
assume added significance. A final, but key,
gredient of success cases was often the pres-
ce of individuals involved in the planning
fort who refused to accept failure and through
fective coordination with all concerned man-
ed to find a way to package the mitigation re-
ests in such a way as to be acceptable to those
volved, particularly the Congress.

B. Planning Agency Support - If we assume
at public support for the conservation of fish
d wildlife resources through the mitigation
ncept is obtainable, then failure to achieve
at end must rest with the "coordinated" efforts
the Federal and State agencies most directly
volved (i.e. Corps of Engineers, Fish and Wild-
fe Service, and State Game and Fish Agency).
e term "coordinated" should be given careful
tention because the record shows that if any
the three principal agencies failed to support
mitigation proposal, the chances of further
nsideration were minimal.

Next to lack of public support, no other
ason for mitigation failure stands out so
early as does opposition to the mitigation rec-
mendations of the FWS. The Corps has consis-
ntly either opposed the majority of the recom-
ndations or proposed their own. In cases
ere they proposed their own, they were usually
rictly structural and minor in nature. There
s and still is an obvious opposition to miti-
tion in the form of land acquisition. However,
should be pointed out that some change from a
gative to a positive attitude seems to be slow-
emerging.

Failure on the part of the FWS to actively seek to educate the public, to influence the CE and the Congress, and a lack of quality reports and follow-through were also major reasons for the unmet mitigation problem. The Service has never had the manpower or funding necessary to effectively influence, report, or follow-through the entire planning and implementation process. This has resulted in a lack of communication, poor quality reports, no reports in some cases, and very little follow-through where success might have otherwise been possible. Furthermore, efforts to bring to the attention of the Congress fish and wildlife resource related concerns have not been adequate.

State game and fish agencies generally review and concur in reports as prepared by the FWS. Their attitude and support has historically been passive in nature. Such passive support did little to achieve mitigation success. In some instances the State took a stronger position than the CE or FWS and was successful in obtaining additional consideration of fish and wildlife problems. In other cases, however, State failure to support recommendations which were acceptable to the Corps and the Service seemed to thwart probable success.

CONCLUSIONS

The intent of the Fish and Wildlife Coordination Act has not been achieved in the Lower Mississippi River Valley. Thus far, there appears to be a hesitancy on the part of the Fish and Wildlife Service and the State game and fish agencies to vigorously support the resolution of fish and wildlife problems associated with Corps of Engineers Water Resource Development activities. Successful mitigation efforts have occured, though they are generally the result of unusual circumstances and not of basic efforts to comply with the Coordination Act.

The unmet mitigation problem cannot be blamed totally on any one group or agency. It appears that only through public support, changing attitudes of construction agencies, better and more Service and State game and fish agency involvement and State and political support will the present trend of not mitigating fish and wildlife losses ever be changed. In the event that some or all of these positive factors happen, there is the possibility of a better track record in the future and maybe even a major effort to collect the unmet mitigation debt owed the public.

Energy Resource Development and Wildlife Preservation[1]

Natalie K. Lobe[2]

Abstract.--Utilizing a case study approach, this paper highlights the major Federal laws and programs which affect energy resource development and wildlife preservation. It is exerpted from an ongoing study which is designed to assist decisionmakers, at Federal, State and local levels in evaluating mitigation strategies such as control technologies, land acquisition, intergovernmental cooperation, and economic incentives.

INTRODUCTION

Rapid industrialization and population growth since the 18th century has brought about an increased demand for energy resources. As a result, this nation has experienced significant depletion of natural resources and damages to our ecological system. From the Council on Environmental Quality (Ninth Annual Report, 1978):

> Extinction of species is the surest way to convert a living resource into a non-renewable resource. Fossil evidence indicates that in prehuman times, mammal and bird species became extinct at the rate of three per century. Since the 16th century the extinction rate has jumped to 150 species each century.

Energy development, from extraction of the resource through waste disposal poses special threats to the delicate balances in our ecological system. Governments at all levels--federal, state, and local have responded to the challenge of meeting energy supply and environmental objectives by promulgating a series of programs and regulations to mitigate or prevent the adverse environmental impacts of energy development.

This paper illustrates a case study approach that will allow decisionmakers at Federal, State, and local levels to evaluate a number of strategies which respond to wildlife preservation programs. These include the application of control technologies, process changes, land use planning, and land acquisition for replacement habitat. The paper specifically addresses the questions:

> a) What are the major environmental issues regarding energy resource development and wildlife preservation?
>
> b) How have the Federal regulations facilitated mitigation strategies to enhance wildlife preservation?

NATIONAL ENERGY PLAN AND DOE

Several basic principles pervade the first and second National Energy Plans (NEP II, 1979):

> The overall environmental impacts associated with energy supply and demand depend on both the types and amounts of energy produced and consumed in the future. The development of energy policy for future years must take into account the environmental implications of alternative energy strategies as well as their technological, economic, and institutional acceptability.

As a consequence, a major mission of the Department of Energy is to encourage and support the expansion of our domestic energy resources without severe degradation to the tural environment. This is not an easy ssion because environmental protection makes ergy more expensive while new energy developnt poses additional environmental risk.

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[1] Paper presented at the Mitigation Symposium, July 16-20, 1979, Fort Collins, Colorado.

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One goal of the Office of Technology pacts under the Assistant Secretary for vironment, in DOE, is to analyze the impacts environmental policies, laws and regulations energy development and use and, conversely, e impacts of energy development on the vironment, health and safety of the nation. thin this office, the Regional Assessments vision identifies and assesses regionally rived health, environmental and social issues, two programs: (1) Regional Characterization d Mitigation Strategies and (2) Regional sue Identification. The Regional Characterition Program describes and analyzes existing ergy related conditions and characertistics the various regions in the U.S. while the gional Issue Identification Program identifies d prioritizes energy and environmental issues a regional context. The Impact Mitigation rategies Subprogram is developing a factbook ich describes federal environmental laws and gulations, and illustrates them with applicable se studies from the energy industry. Its rpose is to shed light on some real world forts to accommodate energy development and vironmental preservation. The forthcoming ctbook covers eight environmental issues th their relevant federal programs, and lustrative case studies. The material for is paper has been extracted from the wildfe section.

CASE STUDIES

Four Federal regulatory programs that ve a direct impact on balancing energy developnt with wildlife preservation are: Section 6 of the Clean Water Act which deals with e effects of thermal pollution; the Fish d Wildlife Coordination Act which covers bitat replacement and protection; the dangered Species Act, and the very recent rface Mining Reclamation Act which, among her things, can prohibit mining in areas ich are the locus of critical wildlife bitats.

The abstracted case studies on wildlife eservation come from a large inventory ich has been assembled by the Regional sessments Division of DOE. The original se studies, covering the eight major environntal issues, came from several sources: A regional offices, State regulatory agencies, vironmental impact statements and various riodicals and journals. Each case study was mpiled from at least two sources of data for ter validation and review by the original formants. Because case studies associated with recent laws and regulations often affect planned or future energy facilities, the issues may not yet be resolved or may still be in litigation. Consequently, these case studies may better demonstrate the issue than the solution.

Section 316 of the Clean Water Act

The Clean Water Act of 1977 contains a section on thermal pollution enforced by the same permits which regulate effluent dischargers.

While Section 316(a) deals with water temperature, 316(b) covers the mechanical effects on fish and wildlife due to high volumes and velocities of water entering and leaving facilities for cooling purposes. Fish are "impinged" when trapped against a screem mesh in the water intake structure, or "entrained" when drawn through the condenser cooling system. In 1977, regulations promulgated under Section 316(a) and (b) were remanded by the courts, partly on technical and partly on procedural grounds. However, National Pollution Discharge Elimination System (NPDES) permits will continue to cite thermal standards, drawing their authority from applicable State water quality standards and from EPA's authority to base permits on "best engineering judgement." Industries which do not comply with the 316(a) and 316(b) provisions may "demonstrate" that their discharges are not adversely affecting the environment. Energy facilities most impacted by the 316 regulations are electric power plants which use large amounts of water for cooling purposes.

The following cases highlight the two major strategies for dealing with fish impingement and entrainment: namely, the institution of a control technology and the utilization of a "316 demonstration" that adverse impacts will not occur.

o *Nine Mile Point, a nuclear power plant in Oswego County, New York, found two separate solutions to the thermal requirements of the Clean Water Act: retrofitting the cooling system in an existing structure, and incorporating a new type of cooling into the design of a proposed structure. Of their two nuclear units, Unit 1 was constructed prior to the 1972 regulations on water quality and Unit 2 was designed prior to the EPA 1974 effluent guidelines. Directed by time and cost considerations the company elected not to retrofit Unit 1 but to "demonstrate" instead, that although the existing cooling system caused a temperature increase beyond the legal limit, this had no harmful effect on existing aquatic life in the receiving lake. The company asked for a variance of the regulations but their permit has not yet been granted. For Unit 2, the company chose* *to incorporate a closed circuit cooling system instead of a once-through system which was in the original design. This would cause no temperature elevation to the receiving lake. A changeover to a new design was less expensive than a "demonstration" for Unit 2, because it was a preconstruction change and, furthermore, data was lacking to carry out a demonstration project.*

- *Bowline Point Generating Station, Rockland County, New York, an oil-fired electric generation plant, is trying to comply with the Clean Water Act, Section 316 requirements. In 1970, the company had been issued a permit from the Army Corps of Engineers to construct a channel and discharge piping for a once-through cooling system, but the Hudson River Fishermans Association filed suit on charges of entraining fish eggs and juvenile striped bass. The result was a decree ordering the plant to reduce its operation during the 1974 spawning season. The Army Corps of Engineers was also ordered to prepare an environmental impact statement for this project. In 1975, EPA issued a NPDES permit under the Clean Water Act which was contingent upon the plant converting to a closed cycle cooling system to avoid inpingement and entrainment. EPA hearings have followed. Meanwhile the Army's EIS pointed out some less costly intake modifications. It appears that actions by the two federal agencies are proceeding independently. To date there is no resolution. This case highlights institutional problems affecting compliance.*

Fish and Wilflife Coordination Act

Administered by the Fish and Wildlife Service of the Department of the Interior, the Fish and Wildlife Coordination Act, amended in 1967, is limited to coordinating wildlife conservation programs with water resource development projects. Typical energy projects affected include hydroelectric development, transmission lines that travel through navigable waters, and dredging associated with oil and gas. Most projects subject to the Coordination Act involve dredge and fill or construction permits issued by the Army Corps of Engineers.

The Act does not allow Fish and Wildlife Service to veto any project but requires that this Agency be consulted on Federal water projects. Consultation takes the form of recommendations and specific plans to "preserve" and "enhance" wildlife impacted by water projects. The agency prepares formal Habitat Evaluation Plans whereby the habitat of each species that may be adversely affected is evaluated by its
size and quality. The project or industry is
then expected to provide for this displaced
species by improvements to the project land o
by purchasing replacement land suitable for a
wildlife habitat. This is referred to as "mitigation." Enhancement of wildlife is also encouraged, but because 100% Federal
funds are not available for enhancement it ha
not been actively pursued.

Strategies which may effectively respond
the provisions of this Act are: purchase of
off-site replacement habitat, providing on-si
habitat improvement or engineering solutions.
The following cases illustrate these strategi
some of which appeared to work successfully within a regional context.

- *Brazos River Authority, a Texas River Auth*
  will provide a replacement wildlife habit
  order to obtain a permit for the Robertso
  Dam in East Central Texas. The dam will
  constructed to provide a lake to supply c
  ing water for proposed coal-fired electri
  power plants in the area. This project w
  destroy 10,000 acres of wetlands and 5,20
  acreas of other habitat. The area suppor
  deer, bobcats, mallards, wood ducks and o
  species. Although the company had a perm
  from the State of Texas, in 1976 the Arm
  Corps of Engineers assumed responsibility
  for issuing permits. Consultation occurr
  between the Corps and the Fish and Wildli
  Service, the latter preparing a Habitat Evaluation Plan. The resultant report
  recommended denial of the permit unless t
  company made certain modifications: purc
  of 15,800 acres adjacent to the site for
  management by the Texas Parks and Wildlif
  Department; incremental filling of the la
  and controlling downstream releases to a
  volume. On the grounds that neither the
  Federal Government nor the Authority coul
  directly purchase this land for the State
  Texas to manage, in a compromise solution
  the Authority decided to grant $500,000 t
  the U.S. Fish and Wildlife to be turned o
  to the State of Texas to acquire replacem
  land. This sum, however, would allow for only 5,000 instead of the original 15,800
  acres. This case illustrates a solution
  a replacement habitat. Problems of Feder
  and State jurisdiction had to be resolved in the process.

- *Pacific Power and Light Company redirecte*
  a proposed 500 KV power line in order to protect a waterfowl habitat which was threatened. The proposed line from Midpoint, Idaho, to Medford, Oregon would
  cross the Klamath River Basin which suppo
  180 species of waterfowl. Because the pr
  prosed route of the powerline would be

erpendicular to the daily feeding flight f the birds, many would be destroyed by lectrocution. In reviewing the Draft nvironmental Impact Statement by the Bureau f Land Reclamation for a permit to cross 'ederal lands, the Fish and Wildlife Service ecommended two alternatives: 1) relocating art of the line to bypass the major feeding reas, and realigning it to run parallel nstead of perpendicular to the feeding lights, or 2) putting it underground. acific Power and Light elected to relocate he line. Although construction of the ransmission line has been delayed by itigation for other reasons, this treatment of the wildlife habitat problem appears o be satisfactory. It should also be noted hat the role of the U.S. Fish and Wildlife as limited to a reviewer of the Impact tatement. This case demonstrates 1) the alue of an EIS review and 2) the application f research on wildlife feeding flights, and) an engineering solution to the problem.

he Grayrocks case which is described in the ollowing section under The Endangered Species ct, is also an excellent example of wildlife rotection at the existing habitat instead of n off-site replacement.

The Endangered Species Act (1973)

This Act protects species and subspecies sh, wildlife and plants in danger of exion by prohibiting their use in commerce, y protecting their critical habitats. It rough the latter that the Act applies to y projects. For example, critical habitats e impacted by inundation from reservoirs d by both hydroelectric and thermal power s, by electrical hazards from transmission , and by oil spills from tankers and pipe- . This Act is administered by the U.S. and Wildlife Service of the Department of ior.

The list of endangered species is develop- y the Department of Interior in consulta- with the Department of Commerce. Critical tats are any air, land or water area, or tituent thereof, the loss of which would eciably decrease the likelihood of the ival of species on the list. Section 7 of Act requires that any Federal action must that it does not adversely affect the cal habitat of an endangered species. The oes not, however, distinguish the relative to society of one species over another; urbish lousewart receives the same protect- s the bald eagle--the national bird.

Many of the strategies which respond to the ife Coordination Act also apply to the gered Species Act.

- *The most published endangered species incident concerned the Tellico Dam Project, where completion of the dam was cancelled on the grounds of a threat to the snail darter--a decision which was upheld in the Supreme Court in 1978. The 1978 Amendments to the Act established a secretary-level exemptions committee to consider exemptions on a project by project basis. This committee denied Tellico the exemption, but economic, not environmental, considerations were the main reasons.*

- *Gray Rocks Dam and Reservoir in Southeastern Wyoming posed a threat to the whooping crane habitat. The project will provide cooling water for Basin Electric Power Company's Laramie River Power Plant. Two hundred miles below this site, along the North Platte River, is a 60-mile stretch of meadowland which provides a resting and feeding place for migratory whooping cranes. The dam and reservoir threatened the reliable river flows necessary to preserve this habitat. Construction was stopped because of a lawsuit by the State of Nebraska and two wildlife conservation groups on the ground that the EIS (prepared by the Rural Electrification Administration) was deficient and that violation of the Endangered Species Act had occurred because Fish and Wildlife had not been consulted. An out of court settlement, which was accepted by the Endangered Species Exemption Committee authorized completion of this project subject to: 1) curtailing the quantity of cooling water withdrawn to protect instream flow requirements, 2) prohibiting an expansion of the company's water rights in the area, and 3) establishing a 7.5 million dollar trust fund to ensure the protection of the endangered species. Administered by the State, the power company, and the National Wildlife Fund, the trust fund will be used for research, land and water acquisitions and modifications to the habitat. This case is important for 1) a precedent-setting trust fund, 2) protection at the existing habitat instead of a replacement strategy, and 3) resolution of an interstate water rights problem.*

- *Dickey-Lincoln hydroelectric project plan for northern Maine which began in the 1960's, will have to be modified to avoid destroying the habitat of the furbish louse wart--an endangered plant species. In their formal biological opinion, the U.S. Fish and Wildlife Service proposed a series of solutions which included further research, transplanting, monitoring and purchase of replacement areas. No construction can be authorized until the Corps of Engineers files an acceptable Final Environmental Impact Statement. This, in turn, awaits further study on the furbish lousewart as outlined by the U.S. Fish and*

Wildlife Service.

Surface Mining and Reclamation Act

Passed in 1977, this Act sets up requirements for state plans controlling strip mining. Wildlife is given particular attention. First, mining can be prohibited on coal bearing lands which are classified as "valuable" and "critical" habitats for fish and wildlife or endangered species. This provision effectively extends the authority to preserve endangered species to non-federal lands and non-federal activities. Secondly, once a mining operation has begun the operation must create a fish and wildlife plan that assesses the impacts of the mining on wildlife and describes appropriate mitigation measures. The Act also obliges the operator to enhance wildlife resources wherever possible. How well these regulations will work in practice is not yet known nor are there any available case studies to demonstrate their applicability to energy projects.

CONCLUSION

Case studies which illustrate the application of wildlife preservation programs to energy development show how government and industry have attempted to meet the continual challenge of expanded energy development without major damage to air, land, and water which form essential wildlife habitats. That many of these cases have not yet been resolved in a way that satisfies both environment and energy objectives is demonstrated in the number that are still in litigation, or the number for which a permit has been denied. The educational value of the case studies, however, lies with an empirical demonstration that:

- o Energy resource development and wildlife preservation can be attainable goals.
- o Federal laws can translate these goals into reasonable requirements.
- o Interjurisdictional regulations on Federal/state and local levels can be resolved so that a proper balance on energy-resource development, environmental protection, and wildlife preservation can be achieved.

More important than a review of strategies which apply to current technologies is the applicability of these strategies to future energy development. The case studies of today may provide some helpful tools and insights for a future world in which expanded domestic energy resources can take place without major degradation of the environment.

NOTE: The information in this paper is based on the research and working papers of Urban Systems Research and Engineering, Cambridge, Massachusetts, under contract with the Department of Energy.

Successful and Potentially Successful Measures to Protect and Improve Fish and Wildlife Habitats[1]

James E. Olson[2] and Gerald C. Horak[3]

This paper will present information from a recently completed handbook on habitat improvement measures. Measures to be discussed involve improvement possibilities for reservoir water-level management, fish propagation and control, wildlife protection at canals, and others. Specifics concerning design, implementation, cost, and effectiveness will be presented.

INTRODUCTION

The achievement of successful measures for
protection of fish and wildlife resources
its simplest form consists of three steps:
mulation of a recommendation by fish and wild-
e agencies; negotiation for a measure accept-
e to the fish and wildlife agencies and pro-
t sponsors and also consistent with the objec-
es of the project; and implementation and
ntenance of the accepted measures by the
ncy operating the project. Fish and wildlife
ision-makers have tended to accept *ex ante*
lysis without an adequate determination of
validity of such analysis (Davis *et al.*
3). As a result, they have lacked the in-
mation necessary to improve the process of
mulating, negotiating, and implementing
sures to protect and improve fish and wild-
e resources. The effectiveness of previous
isions can only be determined by *ex post*
luations. Results of specific undertakings
uld be examined and the information fed back
o the decision process so that the most ben-
cial techniques can be emphasized.

This paper discusses the *Western Reservoir*
Stream Habitat Improvements Handbook (Nelson
al. 1978) which was developed to document the most historically effective fish and wildlife habitat and population improvement measures for water resource development projects. The handbook is intended to aid administrators, biologists, and engineers of fish and game and construction agencies in project design, construction, and operation phases affecting fish and wildlife. The handbook was prepared with two main initial inputs; the first and foremost was a case study analysis of 90 water development projects in 19 western states. These 90 were picked from over 500 possible projects because they included measures for habitat and population improvement and because information was generally available to assess the effectiveness of the measures. At the 90 projects, approximately 286 individual improvement measures were implemented. These were the subjects for this portion of our study.

The second input was a literature review conducted concurrently with the case study analyses. This provided information on newer measures still being tested and also backup information for the measures found in the project reviews. A preliminary handbook was then prepared and reviewed at three technical review sessions in Portland, Albuquerque, and Denver. Representatives of construction agencies and state and federal fish and wildlife agencies attended. The final handbook is a compilation of the original findings of the project and literature reviews and the comments and recommendations received at the review sessions. The handbook discusses 60 different improvement measures divided into two broad categories; those which deal primarily with habitat improvement and those which deal primarily with population improvement. Table 1 delineates this classification and lists the measures in each category and sub-category. For this paper, 6 of the more promising and effective measures were selected for discussion to demonstrate the type of information and format in the handbook. They are multi-level intakes, minimum instream flows, isolated oxbows, wetland dredging and diking, artificial spawning channels, and escape ramps.

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[1] The Mitigation Symposium, Fort Collins,
orado, July 16-20, 1979.

[2] Mr. Olson is an Aquatic Biologist at
iro Control, Inc. in Fort Collins, Colorado.

[3] Mr. Horak is Manager of Enviro Control's
ern Office in Fort Collins, Colorado.

Table 1: Classification of improvement measures from the Western Reservoir and Stream Habitat Improvements Handbook.

HABITAT IMPROVEMENT MEASURES

Reservoir Flood Basins
- Selective Clearing
- Brush Shelters
- Tire Shelters
- Other Fish Shelters
- Exposed Area Planting
- Raised Spillways

Reservoir Conservation Pools
- Stage Filling
- Fluctuation Control
- Seasonal Manipulation
- Minimum Pools
- Aeration-Destratification

Dam Discharge Systems
- Low-Level Intakes
- Multi-Level Intakes
- Spillway Deflectors
- Stilling Basins

Streamflows, Riffles, & Pools
- Minimum Flows
- Fluctuation Control
- Reregulating Dams
- Maximum Flows
- Current Deflectors
- Check Dams
- Other Instream Devices
- Artificial Meanders
- Isolated Oxbows

Streamside Protection
- Bank Cover
- Bank Stabilization
- Snag Clearing

General Practices
- Food and Cover Planting
- Browseway Clearing
- Grazing Control
- Fish and Waterfowl Ponds
- Wetland Dredging and Diking
- Macrophyte and Algae Control
- Settling and Retention Basins
- Land Acquisition
- Reservoir and Flood Plain Zoning

POPULATION IMPROVEMENT MEASURES

Fish Propagation
- Fish Hatcheries
- Nursery and Rearing Ponds
- Nursery Cove Barriers
- Spawning Bottom and Marsh
- Spawning Riffles
- Artificial Spawning Channels

Fish Passage
- Trap and Haul Systems
- Fishways
- Conduits and Culverts
- Turbine Bypasses

Fish Stocking and Control
- Fish Stocking
- Fish Screens
- Barrier Dams
- Other Control Devices
- Fish Eradication

Wildlife Propagation and Control
- Nesting Structures
- Nesting Islands
- Passable Fencing
- Guzzlers, Waterholes and Springs

Wildlife Protection At Canals
- Conduits and Canal Covers
- Impassable Fencing
- Wildlife Crossings
- Escape Ramps
- Other Protection

FINDINGS

The first improvement measure is the installation of multi-level intake structures on dams. The purpose of these intakes is to permit selection of discharge water from various reservoir strata primarily to optimize downstream water temperatures for particular fish species. The mechanism for this purpose may be located on the dam face or within a tower in the reservoir. Intakes may be at fixed depths with closable ports or a variable-level system with sliding shutters may be used. Multi-level intakes can be retrofitted to existing structure as was done on Flaming Gorge Dam, Utah. Secon arily, these intakes can aid in the control of downstream water quality parameters other than temperature, such as the amount of dissolved gases and dissolved solids. Mathematical mode for the prediction of reservoir thermal strati fication are available (King and Sartoris, 197 to assist in the design of intake elevations and operation.

The major constraint on the use of multi-level intakes is handling the trade-offs between temperature requirements of coldwater an warmwater fisheries downstream from the reservoir outlet. Also, multi-level intakes are co siderably more expensive to construct than sta dard discharge systems. An additional conside ation in some reservoirs is the increased difficulty in screening multi-level intakes to pr vent loss of fish in the released water.

All three multi-level intakes evaluated i the project investigations (New Bullards Bar I California; Oroville Dam, California, and Fall Creek Dam, Oregon) were assessed to be success Adjusted to 1977 dollars, the Oroville intakes cost $16,400,000, whereas $1,400,000 was requi to install the New Bullards Bar multi-level in takes. The retrofitted multi-level intake on Flaming Gorge Dam cost approximately $4.5 mill (1977 dollars) according to the Bureau of Reclamation.

Water may be withdrawn from reservoirs through multi-level intakes to provide instrea flows. Minimum instream flows provide for fis passage upstream and downstream, maintenance and propagation of existing fish populations, and establishment of different populations tha existed prior to a dam and reservoir project. Minimum flows are designed to maintain a satis factory combination of pools and riffles for f food production, fish cover and escape. Flows are needed especially during the summer to pre vent dewatering which can result in high fish mortality from stranding in streambeds. Also, though frequently receiving less emphasis, instream flows help retain riparian vegetation a wildlife habitat and provide sources of water for adjacent ponds and wetlands. A number of methods have been proposed to determine instre flow requirements for fish and wildlife. An excellent summary and discussion of these meth ods is available (Stalnaker and Arnette eds. 1 to assist biologists in determining flow needs For the most up-to-date information on instrea flow methodologies, the U.S. Fish and Wildlife Service Cooperative Instream Flow Service Grou in Fort Collins, Colorado should be contacted.

Western State water laws and administrative regulations frequently place severe limitations on water allocations for fish and wildlife. In many States, an instream flow for protection of fish and wildlife is not recognized as a beneficial water use. Therefore, water cannot be appropriated or reserved, or water rights purchased, for fish and wildlife instream needs. Even where such flows are recognized as a beneficial instream use, they still may be legally challenged. Another major constraint on reserving instream flows for fish and wildlife preservation is the resulting loss of reservoir storage capacity and yield for irrigation, power production, water supply, and other economic purposes. In the absence of strong public pressure or obvious economic benefits from instream flow protection for fish and wildlife, economic development interests such as irrigation, hydroelectric, and water supply needs, have generally prevailed over recreation and preservation interests.

Sixty-two percent of the 44 cases where ecommended instream flows were implemented to high degree were judged to have a successful utcome. Other case study investigations have eported that minimum instream flows generally ave maintained fish and wildlife habitats, lthough population curtailments sometimes were ignificant (Nelson et al, 1978). Good results n preserving habitats have depended on sound etermination of instream flow needs and secure eservations which are honored by dam and resrvoir operating agencies.

Costs for meeting minimum instream flow equirements are difficult to isolate since the pecified flow quantities may partly or wholly eet other downstream project needs such as urnishing water for irrigation, municipal use, nd water quality management. However, in some tates the direct purchase of appropriative ater rights for fish and wildlife purposes is ermissible. For example, a 1-cfs water right as purchased along Boulder Creek, Colorado, or $18,000 (1977 dollars). The cost of water ights will range widely depending on factors uch as the location, prior use, and seniority f the right.

The next improvement measure involves islating oxbows in rivers which are being traightened or channelized. An example of his is Deer Island and Deer Lake on the Coloado River below Parker, Arizona. By incororating water control structures in the dikes solating the oxbow, inflow and water level can e managed. This provides a more stabilized treambed and streambank for increased fish and ildlife production and also improvements in ater quality through reduction of turbidity evels.

Construction requirements for this measure often include dredging to increase water depths. Also, diversionary water rights are sometimes necessary to compensate for the evaporation losses from the standing water. However, the areas developed by the use of this technique have proven to be outstanding successes in terms of the habitat provided for fish and wildlife. Production at the Deer Lake area has far exceeded pre-project expectations. Construction costs for the area, adjusted to 1977 dollars, were $777,000 with annual operation and maintenance costs estimated at 1 percent of the capital outlay.

The next improvement measure concerns the dredging and diking of wetlands. This measure is undertaken to increase the water level and manageability of wetlands and to create additional wetland habitat. Water control structures, installed in the dikes, allow for management of pool levels. Open water interspersed with marshland and interlaced with ditches and high spoin banks provide habitat favorable to many forms of game and non-game wildlife.

One area where this measure has been employed is the Topock Marsh Unit in Arizona. There, wetland dredging and diking have successfully produced habitats for fish, waterfowl, and marsh birds such as the endangered Yuma clapper rail (Deason and Sharpe, 1978). In fact, the increase in the Yuma clapper rail population has been greater than expected. Dredging and diking also has improved water circulation; reduced water temperatures, pH levels, and turbidity; and isolated areas where undesirable water quality conditions are extreme. Another example of this technique is at the Garrison Project in North Dakota where diking has been credited with significant increases in waterfowl use as well as the establishment of pheasant, whitetailed deer, and other wildlife in the vegetation along the banks.

An important consideration when diking is the possession of adequate water rights to fill the impoundment and replace annual evaporation losses. This was a limiting factor for the Topock Marsh Unit development. Also, the costs of this improvement measure can be substantial depending on the height of dike or depth of dredging and the type and number of outlet controls installed in the dikes. For the Topock Marsh Unit, the costs of dredging and diking were approximately $600,000 in 1977 dollars. This development involved 6.2 miles of diking with five control structures, 7.4 miles of channels, 2.1 miles of artificial islands, and the evacuation of a silt basin at the entrance of the inlet channel.

The next improvement measure, artificial spawning channels, are constructed as alternatives to fish hatcheries. The channels are built for coldwater anadromous fish, primarily salmon. Their purposes are to supplement the natural spawning habitat or to replace habitats lost from construction of dams or other structures. The project investigations covered the spawning channels incorporated into the Tehama-Colusa Canal along the Sacramento River in California. These facilities, constructed by the U.S. Bureau of Reclamation as part of the Central Valley Project, consist of three separate spawning channels. The uppermost section of the canal is a dual-purpose channel. It functions both as an irrigation canal and spawning channel. The bottom of this section is covered by gravel and boulders, 2.5 to 3 feet in depth, to provide suitable habitat for the spawning salmon. Approximately 3.2 miles downstream from the headworks, the canal is divided into a standard irrigation canal and two additional spawning channels. This area is shown in figure 1. The twin spawning channels are each approximately 1 mile long and have the same 2.5 to 3-foot gravel bed. The combined spawning area provided by all three channels exceeds 2 million square feet. The twin channels join downstream to form an access channel that empties into a tributary of the Sacramento River. An electric weir across the tributary directs migrating salmon into the spawning facilities. Other appurtenances include a settling basin at the headworks to remove silt; a drum screen complex to prevent downstream-migrating fry from entering the irrigation canal; and various counting facilities to record salmon useage.

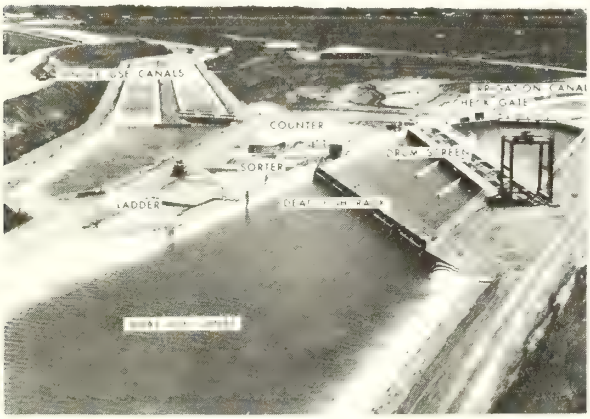


Figure 1.--A downstream view of part of the Tehama-Colusa Fish Facilities near Red Bluff, California. Shown here in the foreground is the dual use (spawning and irrigation) canal, on the left are the twin, single use spawning channels, in the upper right is the irrigation canal, and in the center are various other appurtenances. U.S. Bur. of Reclamation photo.

These facilities have proven to be quite successful. Approximately 5,000 fish use the spawning channels each year and it is expected that this number will grow as more fish return after hatching at Tehama-Colusa. A portion of this success is attributed to excellent water percolation through the channel beds. This is a critical factor in producing more rapid hatching and greater survival of the fry.

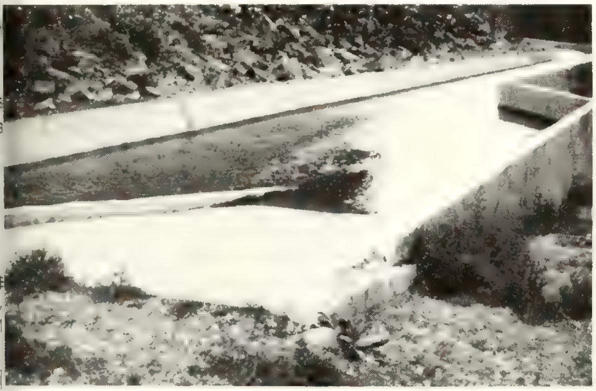
While costs for artificial spawning channe are substantial, they may be significantly less than for a hatchery of equal production capacit Maintenance and personnel requirements also may be less for the spawning channels (Clay, 1961). Another advantage is that, in situations such a the Tehama-Colusa, some of the needed facilitie already exist and a spawning channel can be incorporated with less new construction. In some applications, spawning channels may serve secondary functions such as carrying flood flows. Disadvantages of the channels include the need for gravel cleaning and the compromising effect on hydrologic characteristics of canals.

The next measure deals with a problem encountered on irrigation canals common in the western states. When a concrete-lined, open canal passes through suitable big-game habitat, animal losses due to drownings and related injuries normally number one or more per mile of canal per year (Latham and Verzuh, 1971). Approximately 95% of the animals lost are deer. Reasons for entering the canals appear to include attraction to the water for drinking, attempts to cross the canal to follow daily or seasonal migration patterns, and panic entries caused by pursuit of predators. Once in the canals, the high water velocities and slick, steep canal walls make it virtually impossible for the animals to escape unassisted.

Many devices have been tried to solve the problem. Fencing, wildlife crossings, and drinking bays have shown some effectiveness in certain situations. This discussion, however, deals with escape ramps, designed to aid animal in getting out of the canals once they have gotten into them.

The first attempts at providing escape ramps included metal or wood cleats, reinforcir bar mats and ladders, and asphalt pads attachec to the canal walls. By themselves, these ramps were seldom if ever used and in some cases appeared to frighten animals away from them. The next refinement was a deflector built directly into the canal to guide swimming or floating animals toward the ramp. This combination showed some effectiveness particularl on the Ainsworth Canal in Nebraska where deflectors were used in conjunction with wooden cleats on the canal walls. However, the deflectors tend to collect debris from the water causing reduced flows and a general nusiance for canal operators.

Another type of escape ramp, the Richmond deer escape, was originally designed and built into the Okanagon Canal in British Columbia (Seaman, 1977). The principle of this device is that, by rapidly widening the canal, a circular or eddy current is formed in a recess in the canal wall (figure 2). A floating or wimming animal coming down the canal will be rawn into the recess by the eddy current. On ne side of the recess, a low-gradient (3:1 or :1) ramp is provided that is roughened or rooved which the animal can use to climb out f the water. Recently, these devices have been nstalled on the Howard Hansen feeder canal, art of the Colorado-Big Thompson Project in olorado.



igure 2.—A downstream view of a Richmond deer escape showing the recess on the canal wall and the low-gradient ramp. U.S. Bureau of Reclamation photo.

The Richmond deer escape is a relatively ew device and conclusive evidence of its ffectiveness is still forthcoming. On the oward Hansen canal, the ramps are being montored by electric eye trips and infrared camera quipment. Costs for the ramps vary depending n the amount of rebuilding necessary to comlete an installation. An excellent possibility or retrofitting a canal with these devices ccurs when concrete slabs making up the canal alls are replaced as part of routine maintennce. The amount of additional effort needed o construct the ramps is reduced significantly, onstruction equipment and personnel are present, nd costs are much less.

CONCLUSION

The measures presented in this paper and the majority in the Western Reservoir and Stream Habitat Improvements Handbook can be retrofitted on projects which are already authorized, under construction, or completed. Many of these measures do not require acquisition of large tracts of land, but can be applied on project lands. However, these measures cannot be retrofitted unless professionals from fish and wildlife agencies as well as construction and permitting agencies consider them on a project-by-project basis. This is a departure from past practice, where only projects in the "planning" phase received consideration for mitigation and enhancement. Fish and wildlife mitigation and enhancement must become dynamic forces in resource development projects. As projects change in emphasis over time so must the inclusion and implementation of fish and wildlife measures.

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Grayrocks—A New Approach to Mitigation [1]

Constance M. Bowen[2]

Abstract.--A $7.5 million trust fund to protect the habitat of the endangered whooping crane solved the environmental problems surrounding the Missouri Basin Power Project, better known as "Grayrocks." This new approach to mitigation, uniquely suited to the Grayrocks situation, may be inappropriate under different circumstances.

In the early 1970's a regional network of rural electric cooperatives launched plans to build a large coal-fired generating plant near Wheatland, Wyoming, to supply power to rural and municipally-owned systems in eight states. Called the Missouri Basin Power Project (MBPP), the $1.6 billion development became commonly known as "Grayrocks," the name of the dam and 100,000 acre-foot reservoir on the lower Laramie River designed to supply cooling water to the project's 1.5-million kilowatt generating station.

The Laramie River is a tributary of the North Platte River, which joins the South Platte in Nebraska to form the Platte River, flowing eastward throughout the length of the state. Nearly 300 miles downstream from Grayrocks in central Nebraska lies the "Big Bend" of the Platte, heavily utilized by migratory waterfowl and containing an area declared Critical Habitat for the endangered whooping crane. Between the Big Bend of the Platte and Grayrocks stands Kingsley Dam, impounding flows of the North Platte in Lake McConaughy, a 2-million acre-foot irrigation and hydro power reservoir managed by the Central Nebraska Public Power and Irrigation District (CNPPID) (fig. 1).

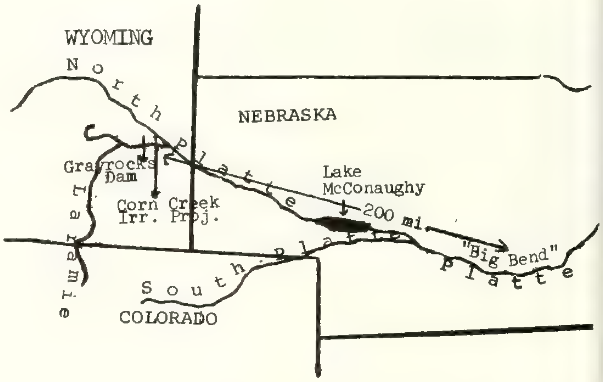

Figure 1.--Geographic arena of the Grayrocks controversy.

GRAYROCKS, A TROUBLED PROJECT

Grayrocks' history has been marked by controversy. Insurmountable obstacles seemed certain to delay the project if not halt it altogether--lawsuits by the state of Nebraska and private landowner groups in Wyoming over water, and by national and state conservation organizations concerned about possible adverse impacts on migratory waterfowl habitat downstream; stymied federal construction permits; a court-ordered shut-down on construction; a requirement to assess the impact of Grayrocks in concert with all other projects planned in the Platte Basin; irreconcilable conflict with the Endangered Species Act for possible impact upon the habitat on the Big Bend of the Platte in Nebraska of America's most revered endangered species, the whooping crane.

Within a few short weeks early in 1979, however, these obstacles which had loomed so large were swiftly overcome. Grayrocks is expected to begin producing power in the spring of 1980, only slightly behind schedule. A delivere arrived before it became necessary to halt work on the project for as much as one, single day.

The instrument delivering the knockout punch to Grayrocks' problems was an out-of-court "Agreement of Settlement and Compromise" (the Agreement) forged by disputing parties, and

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 17-19, 1979.

[2] Executive Director, Nebraska Wildlife Federation, Firth, Nebraska.

igned on December 4, 1978. The Agreement con-
ined three basic provisions: Reduction in,
d replacement of a portion of, the water to be
nsumed by the project; guaranteed releases
om the reservoir to the mouth of the Laramie;
d a cash outlay by the MBPP of $7.5 million
r a whooping crane trust fund to preserve and
hance migratory waterfowl habitat along the
g Bend of the Platte in Nebraska.

THE TRUST FUND, A NEW SOLUTION

Adjustments in water consumption and speci-
ied streamflows are not new in mitigating habi-
t losses from water development projects.
e $7.5 million Grayrocks wildlife trust fund,
wever, is.

Events following the Agreement show clearly
at the hero of the hour which so quickly
eared the stubborn obstacles from Grayrocks'
th was the $7.5 million trust fund, an unpre-
dented tool for protecting endangered species
der federal law and for resolving environmen-
l lawsuits. On January 23, 1979, Grayrocks
came the first project to be exempted from
ovisions of the Endangered Species Act (ESA).
e exemption was ordered by unanimous vote of
e cabinet-level interagency Endangered Species
mmittee, created by the 1978 Amendments to the
A (with Grayrocks in mind) to resolve irrecon-
ilable conflicts between development projects
d endangered species. The Committee found the
greement of Settlement and Compromise to pro-
ide "reasonable mitigation and enhancement
asures which are necessary and appropriate to
nimize the adverse effects of the project on
e whooping crane or its critical habitat."
e order exempting Grayrocks was conditional,
provided that the mitigation and enhancement
asures ... are funded concurrently with other
oject features, paid for by the Missouri Basin
wer Project," and carried out regardless of
e final outcome of pending litigation. With
e Committee's order the $7.5 million trust was
ssured, despite a stipulation in the Agreement
self that it would be considered null and void
less the Court's judgment enjoining the pro-
ect was vacated and pending litigation was
smissed "with prejudice," meaning it could not
reinstated at a later date.

The Endangered Species Committee's order
me on the heels of a long-awaited biological
inion by the U. S. Fish and Wildlife Service
WS) a month earlier on Grayrocks' impact on
e whooping crane. Issued four days after the
greement was signed, the opinion stated that
e Grayrocks Dam and Reservoir, when con-
dered along with other planned water develop-
nt projects in the Platte Basin, was likely
jeopardize the continued existence of the
ooping crane and to destroy or adversely modify
e crane's Critical Habitat on the Big Bend of
the Platte in Nebraska. The FWS opinion identified two alternatives to offset the impact: Replacing a portion of the water consumed by the project each year; or establishing "an irrevocable trust" to generate income sufficient to insure maintenance and improvement of whooping crane habitat. A year earlier the FWS had been able to determine only that Grayrocks may jeopardize the whooping crane, but that a biological opinion must await proposed studies expected to take three years to complete.[3]

On March 1, 1979, the Eighth Circuit Court of Appeals, which had stayed the injunction against further construction awarded by the Federal District Court for Nebraska, approved the settlement and instructed the District Court to vacate judgment and dismiss the suit with prejudice, dispelling the legal cloud which had hung over the project for more than two years.

The clout which events in retrospect reveal the trust fund concept carried will surely make this a tempting approach to mitigation in the future. The trust fund could well become "the mitigation bandwagon" to climb aboard. Recently, for example, the news media carried an item datelined Omaha that a trust fund is being considered to compensate for fish and wildlife habitat losses caused by Corps of Engineers projects along the Missouri River below Sioux City, Iowa, since 1912; "a cash settlement similar to the $7.5 million trust fund promised by backers of Wyoming's Grayrocks Dam to protect a critical Platte River habitat for whooping cranes and other migratory waterfowl."

The trust fund concept as a tool for mitigation must, I believe, be approached with considerable caution. Its appeal in the case of Grayrocks was born of circumstances for which the approach was uniquely appropriate, as a closer look at the issues may demonstrate.

THE WATER ISSUE

The Laramie River Basin's 143,000 acre-feet (a-f) annual yield over a twenty-year period represents about 12 percent of the annual yield of the North Platte Basin to the Nebraska-Wyoming state line. The North Platte is among the most highly regulated and utilized rivers in the U. S., with considerable wintertime flow storage capacity. Little regulation occurs through reservoir storage and release on the Laramie, however, which moves freely downstream for storage in Lake McConaughy.

The U.S. Supreme Court in 1945 issued a decree allocating North Platte River water between Colorado, Wyoming and Nebraska, interpreting 30,000 pages of testimony which had accumulated over a period of nine years. The decree entitles Nebraska to 75 percent of the flows of the North Platte between May 1 and September 30 of each year. Although the decree does not specifically refer to the Laramie, it can be argued by implication that Nebraska is also entitled to 75 percent of the May-September flows of this major tributary of the North Platte. This was the reasoning, at any rate, when in November, 1976, Nebraska's Attorney General filed suit against Grayrocks--despite the fact that MBPP power users included the municipally-owned Lincoln Electric System (LES) in eastern Nebraska (13 percent owner of the project) and rural electric cooperatives in the Nebraska Panhandle.

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[3] Memorandum of decision, U.S. District Court for the District of Nebraska, Oct. 2, 1978, p.24.

Initially the MBPP proposed to consume a maximum of 61,650 a-f of water annually from the Grayrocks Reservoir--a 43 percent depletion of the Laramie Basin's average annual yield--30,650 a-f for cooling water, 8,500 a-f for evaporation and 22,500 a-f for the Corn Creek Irrigation Association, in exchange for their prior rights to Laramie River water. (The outlook for the Corn Creek Irrigation project, earlier found infeasible by the U.S. Bureau of Reclamation, had brightened with the prospect of a water supply--the Grayrocks Reservoir--without the cost of constructing a storage facility.)

The suit by the state of Nebraska claimed that guarantees of over $1 million in loans to the MBPP by the Rural Electrification Administration (REA) on August 10, 1976, constituted a major federal action which made the project subject to provisions of the National Environmental Policy Act (NEPA). The suit charged that REA's Environmental Impact Statement (EIS) had failed to consider alternatives to the project, or to assess its downstream impacts in Nebraska upon water quality, the trout fishery in Lake McConaughy, warm water fisheries in other reservoirs and sandpit lakes in the Platte Valley, outdoor recreation, groundwater resources, and "habitat for whooping cranes and other waterfowl and wildlife located in and adjacent to the Platte River System in Nebraska, including the proposed Platte River National Wildlife Refuge being contemplated by the United States Fish and Wildlife Service."

The suit was laced with irony. That the wildlife refuge referred to in the suit remains even today "being contemplated" is largely the result of successful opposition by the same irrigation interests which promoted the court action against Grayrocks. Designation of Critical Habitat for the whooping crane along the central Platte in May, 1978, enjoyed an equally unfriendly reception, despite the prominence of this endangered species in Nebraska's suit against the REA on Grayrocks.

State officials made no pretense that the suit stemmed from a newly-acquired environmenta conscience or was other than a water-use and reservoir operations controversy. Others, however, were genuinely concerned about the possib impact of Grayrocks on important migratory waterfowl habitat downstream on the Platte. On March 28, 1977, the Nebraska and National Wildlife Federations and three other conservation groups joined Nebraska's suit against the REA.

THE WILDLIFE ISSUE

The habitat in the central Platte Valley in Nebraska is heavily utilized by migrating waterfowl. Close to a million ducks and geese --including 70 to 90 percent of the midcontinen population of white-fronted geese--use the central Platte and adjacent wetland basins as a major spring staging area. Also each spring 80 to 100 percent of the midcontinent population of lesser sandhill cranes fly non-stop 600 mile from their wintering grounds to the Big Bend of the Platte, crowding into a 150 mile reach wher they spend six to eight weeks gaining up to 20 percent of their total body weight, storing the fat which will enable them to breed and incubat their eggs after completing the long migration north. Finally, Nebraska has more recorded sightings of the endangered whooping crane than all the other states combined. Of the confirme sightings recorded between 1922 and 1975, 77 percent were on or near the Platte River.

The area of primary concern on the Platte extends from Lexington about 75 miles downstrea to Chapman. This portion of the Big Bend receives heavy use by the sandhill crane and contains the reach declared Critical Habitat for the endangered whooping crane.

The attraction of the Platte to crane species stems from two special and unique types of habitat (in addition to grain stubble and alfalfa fields for primary feeding sites): (1) unvegetated, submerged sandbars in broad, shallow stretches of the river for night roost sites; and (2) subirrigated wet meadows for feeding, loafing, courtship and secondary roost The Platte River--described by early settlers a a mile wide and an inch deep--provides the only habitat of this type and quantity within the United States portion of the Central Flyway. Its importance to the survival of the lesser sandhill and whooping crane cannot be overstate The FWS estimates that up to 65 percent of the sandbar and wet meadow habitat within the designated Critical Habitat for the whooping cran has been lost within the past forty years.

The cumulative impact of 43 water storage projects and at least 40 diversions in the Platte Basin in Wyoming, Colorado and Nebraska has been a reduction in flow to 800,000 a-f nea Lexington, where cranes still use the river.

his represents a reduction of 69 percent from
FWS conservative estimate of pristine flows
f 2,600,000 a-f annually in the Platte. At
rady upstream from Lexington, where cranes no
onger use the river, the remaining 420,000 a-f
s only 16 percent of the pristine flows. Pos-
ible future activities and projects in the
latte Basin, including Grayrocks, would reduce
lows at Lexington to 330,400 a-f or less,
0,000 a-f or more below the flows at Brady.

These considerations led the FWS to write
o the Corps of Engineers on December 10, 1976,
upplementing earlier response to Notice of
BPP's application for a Section 404 permit
ddressing only local impacts, recommending that
he permit not be issued. The letter stated,
It is impossible to consider the permit appli-
ation and its impacts upon the Platte River
lows as an isolated situation.... The Fish and
ildlife Service and other governmental agencies
ust now consider the cumulative impacts of the
roposed projects on the Laramie and Platte
ivers. Until ... we are assured the project
y itself and cumulatively will not destroy the
emaining Platte River habitat, the Fish and
ildlife Service recommends that the permit not
e issued." The letter also said that the EIS
n Grayrocks "has never adequately addressed
he impacts of the project on the downstream
sh and wildlife resources, particularly those
n Nebraska," or considered alternatives.

Five months later the FWS reversed this
osition, advising the Corps by letter May 3,
977, that they had withdrawn the recommendation
hat the permit not be issued, having found it
ifficult to factually establish that the pro-
osed Grayrocks diversion alone would cause
amage to the wildlife habitat downstream," and
ting that the adequacy of the EIS was under
tigation. (This position was announced in a
ws release three months later.) Subsequent
rrespondence recommended that the 404 permit
conditioned on implementation of a Memorandum
Agreement between the MBPP and the Wyoming
me and Fish Department to mitigate habitat
sses at the reservoir site.

The Corps issued the 404 permit on March
, 1978. Nebraska and the other plaintiffs
omptly brought suit against the Corps for non-
mpliance with NEPA and Section 7 of the ESA.
e two suits were combined in the trial which
d to the injunction against the project. On
ly 19 an opinion by an Interior Department
licitor determined that the ESA requires
onsideration of cumulative impacts on an
dangered or threatened species ecosystem
fore determining whether a particular project
ll violate the prohibitions of Section 7."
"rule of reason" is to be applied in deter-
ning projects to be cumulatively considered,
sed on the liklihood of their completion.

THE AGREEMENT OF SETTLEMENT AND COMPROMISE

The out-of-court Agreement restricts the amount of Laramie River water Grayrocks can use to a maximum of 40,500 a-f per year, including replacement from other sources of half (11,250 a-f) of the water for the Corn Creek irrigation project, should it be built. This represents a reduction of 20,150 a-f from the maximum originally proposed. Further, the Agreement guarantees releases from the Grayrocks Reservoir to the mouth of the Laramie of 40 cfs (cubic feet per second) during October through March, 50 cfs during April, and 40 cfs or 75 percent of the Laramie's natural flow, whichever is greater, during May through September. These guarantees preclude development of additional generating units for the MBPP, and reduce the liklihood that the project will sell the Corn Creek water rights if that project does not become a reality. Availability of about 71 percent of the Basin yield of the Laramie to the North Platte is thus assured, close enough to the Supreme Court decree allotment to satisfy the state of Nebraska.

Assurances of reduced water consumption and prescribed flows in the Laramie, however, did not satisfy the conservation groups which were parties to the lawsuits, for one simple and compelling reason: Under present federal and state laws, interstate compacts, and court decrees, no means exist to insure that water saved nearly 300 miles upstream will ever reach the habitat on the Big Bend of the Platte. Nebraska law at the present time does not recognize instream uses of natural flows, including fish and wildlife, as "beneficial." Even if the operation of Kingsley Dam and Lake McConaughy provided for release of water to the important waterfowl habitat downstream, which it does not (a fact mercilessly pursued by MBPP attorneys with CNPPID and state agency witnesses during the trial), no authority exists under Nebraska law to administer or enforce maintenance of natural flows in the Platte until they reach the Big Bend. Thus an agreement which merely puts water into the upstream reaches of the Platte Basin in Wyoming cannot solve the problem of maintaining flows for habitat downstream in Nebraska.

THE $7.5 MILLION TRUST FUND

The MBPP's response to continuing concerns of wildlife interests in the suits was the $7.5 million whooping crane trust fund. Exhibit B of the agreement establishes and spells out the provisions of "The Platte River Whooping Crane Habitat Maintenance Trust." Although the whooping crane stars in the title role, the Agreement specifically cites the importance of the habitat on the Big Bend of the Platte to the sandhill crane and "millions of migratory waterfowl," declaring the intent of the trust to be "to protect and maintain ... the physical, hydrological and biological integrity of the Big Bend area so that it may continue to function as a life-support system for the Whooping Crane and the other migratory species which utilize it."

Exhibit B stipulates the following: MBPP's agent is to convey cash in the form of a check in the amount of $7.5 million to the three trustees responsible for administering the trust, one each to be appointed by the MBPP, the Wildlife Federation and the governor of Nebraska. (The trustees will hold their first meeting July 20, 1979, in Grand Island, Nebraska.) Of the $7.5 million principle, $500,000 may be expended during the first year. The remainder is "not to be invaded" except by unanimous agreement of the trustees. On other matters agreement of two trustees is sufficient for action or decision.

The trustees are obligated by the Agreement to develop a written "habitat monitoring plan" to describe changes in riparian, wetland and island habitat in the Big Bend and other segments of the Platte used by sandhill and whooping cranes; to implement the plan under supervision of a technical steering committee composed of qualified ecologists and water resources specialists selected by the trustees; and to issue regular reports on the plan for public distribution. The Nebraska Game and Parks Commission and the FWS may propose appropriate activities to achieve the purposes of the trust, although the trustees are free to act independently of these proposals. Uses specified for the income from investment of the trust, expected to approach $500,000 annually, include but are not limited to research, habitat management and manipulation, acquiring land or interest in land, and acquiring "all types of rights in or to water or water storage."

In this latter provision lies a potentially significant means to provide and legally enforce "a water right for cranes" downstream from Grayrocks on the Big Bend of the Platte in Nebraska. Its significance lies in another fact of Nebraska water law, namely that instream flows which carry a storage-use right are subject to regulation and enforcement. Storage water thus could be apportioned to flow downstream, if the owners of the rights agree, and be subject to enforcement. Water acquired in storage in Lake McConaughy, for example, could be reserved by contract for release to habitat downstream and monitored to insure that it in fact reaches its destination.

At the present time storage in Lake McConaughy is about 200,000 a-f below the intended capacity of the reservoir, the result of an operational decision following windstorm damage to the upstream face of Kingsley Dam in 1972. Theoretically, at least, rebuilding the face of the dam to accommodate full storage in the reservoir (which CNPPID witnesses at the trial estimated would cost $5 million) would allow additional storage water available for release to support waterfowl habitat downstream.

CONCLUSION

The speed with which the trust fund remove the barriers to Grayrocks, permitting construction to continue uninterrupted, shows MBPP got a real bargain. The $7.5 million represents .0047 of the $1.6 billion cost of the project, less than one-half of one percent. The financial impact of a one-year delay, on the other hand, has been estimated at $100 million.

The effectiveness of the $7.5 million trus in preserving the habitat of the whooping crane and other migratory species on the Platte River in Nebraska awaits the test of time. It holds potential for a partial, short-term solution to the problem of diminishing Platte flows through purchase of storage water rights, and may ultimately produce long-term solutions through the studies and monitoring programs it finances. The state of Nebraska, having used the leverage of federal laws designed to protect endangered and other wildlife to get more water entering the state, should now pass legislation to recognize instream uses of water, including wildlife habitat, as "beneficial" under law, thereby permitting use of trust monies to acquire valid instream flow rights to help meet trust goals.

The Grayrocks wildlife trust, unlike more traditional approaches, is not intended for on-site, in-kind mitigation and enhancement. Further, it recognizes responsibility commensurate with the MBPP's being but one of many consumptive users of Platte Basin water, which doe not carry an obligation to protect the entire Platte. Where the need is to mitigate in-kind habitat losses on-site, for which a single project or agency holds direct, total and undisput responsibility, the trust fund approach offers little if any advantage (beyond escaping responsibility and buying off the opposition), and ha definite limitations. Unlike a federal agency, a private trust corporation lacks power of eminent domain or immunity from prohibitions by state legislatures. Assigning responsibility for trust administration to a state fish and wildlife agency carries the additional risks of diversion of trust income to uses not directly related to the habitat base at issue, or to the state's General Fund.

The trust fund approach, like any mitigation and enhancement alternative, must be applied on a case-by-case basis with full recognition of its shortcomings.

Power Plant Cooling Lakes: An Asset to Wildlife and the Environment[1]

William S. Brenneman

Abstract.--The steam, which produces electricity at power plants, is condensed to water with water. In more humid regions the cooling water is obtained from "perched" lakes or dammed streams. Entrainment or impingement, of aquatic life, at the intakes, is inconsequential. In the Midwest a vast heritage of tall grass prairies and sloughs have been transformed into monoculture farmlands. Now cooling lakes, plus their peripheral lands, provide significant habitat for wildlife in an otherwise hostile environment. In addition to quality wildlife habitat cooling lakes often provide recreation, act as "sinks" for suspended solids, and facilitate the recharge of aquifers.

In Genesis I, God said: "Have dominion over the fish of the sea and over the birds of the air and over every living thing that moves upon the earth." Webster defines dominion as the right to control. Considering the above, isn't it man's duty to manage the biota, not extirpate creatures? Illinois Power, like most utilities, is dedicated to such multiple use management, or dominion over, its cooling lakes and surrounding lands. We do endorse the concept of maximizing wildlife habitat and all other environmental potentials of these lands and waters.

The EPA says cooling must be accomplished by the "Best Available Technology" (BAT). (40CFR423) However, they believe cooling towers are BAT not cooling lakes.

Often, at least in the Midwest, cooling lakes are environmentally superior to cooling towers. We would hope in the future the EPA would conscientiously consider approving their use on a site-specific basis. The two basic forms of cooling lakes are:

1. "Perched Lakes" - Dikes are constructed to impound water pumped from adjacent river. They are ideal for fish and waterfowl but have an artificial appearance which may displease some people.

2. Dammed streams - A relatively small stream is dammed to form a lake. The dendritic pattern of the stream and its tributaries results in a more natural appearing lake.

Entrainment and impingement of biota in the cooling water has been of considerable concern to the EPA and some other scientists. New, and some old, technologies greatly minimize destruction of the biota. An older example is Duke Power's Keowee-Toxoway complex (1970) where the water intake is in the hypolimnion. In the hyoplimnion little life exists and entrainment or impingement is small. At our Clinton Nuclear Power Station (under construction) impingement will be minimized by a newer technic of decreased intake velocity. Considering the potential for most life to multiply rapidly to fill any niche, loss from impingement or entrainment is inconsequential. For example, Jim Smithson (Illinois Power Company Aquatic Biologist) tells me the gizzard shad impinged at Baldwin Power Station, in the worst one-week period, would not exceed the number of eggs spawned by a dozen females.

The once vast prairielands and sloughs of the Midwest are now the nation's "breadbasket" and habitat for fish and wildlife has been severely decreased in the process. Midwestern generating stations, which cool with lakes, utilize less than 7% of the total acreage for buildings, etc. The remaining land and water is immediately "homesteaded" by wildlife.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Land Use and Conservation Specialist, Illinois Power Company, Decatur, Illinois.

The foregoing generalities completed, I'll dwell a few minutes on cooling lakes in Illinois. In aggregate, Illinois electric utilities have constructed nearly 23,000 acres of cooling lakes. These lakes and the peripheral lands total over 150,000 acres. Although composing but a fraction of one per cent of Illinois land mass, such areas are environmentally some of the State's most valuable.

Specifically, now, let's consider the wildlife and environmental assets of Illinois Power Company's Clinton Nuclear Generating Station (now under construction).

1. A Haven for Wildlife - Clinton Lake and its environs provide the best wildlife habitat in at least a four-county area. Including the 5,000-acre lake, there are about 14,000 acres of greenery surrounding the power station. This oasis is set in the midst of duoculture of corn and beans in the summer, and a black desert during the winter. Last season nearly 100,000 waterfowl paused to rest and feed at Clinton. A partial list of the rare, endangered, or uncommon species sited at Clinton thus far is:

   Bald Eagle
   White Pelican
   Cooper's Hawk
   Marsh Hawk
   Sparrow Hawk
   Woodcock
   Great Horned Owl
   Great Blue Heron
   Osprey

   The uplands, surrounding the lake, is "home" to about all non-migratory birds and animals found in Illinois. I believe there are more deer, beaver, and fox here now than before Clinton Lake was built.

2. A sanctuary for Plants - Natural areas of timber and prairie have been located, preserved, and expanded. Dr. Paul Shildneck (Decatur, Illinois Botanist) has found nearly 50 vascular plants at the site which were previously unreported for DeWitt County.[1] Some of my lichen specimens, new to DeWitt County, are now accessioned in the Illinois Natural History Survey's Herbarium. A 6-acre prairie remnant has been restored and expanded to nearly 60 acres by seeding and burning. Since the prairie also supports scattered old trees it should be called a savanna. As the soil is forest-derived, it must have been a struggle between trees and grass, with forest usually dominating. Over 300,000 trees have been planted in the old fields and pastures. In the future, the natural areas and tree plantations will be ideal for studying plant succession. These areas will also be richly mantled with species or ecotypes which may be valuable to mankind in the future.

3. Clinton Lake is repository for the soils eroding from a 300 square mile watershed. The two lake inlets are often muddy when the spillway water is clear. The lake was constructed to accomodate this deposition of sediment. Of course, we do wish the sediment load was greatly decreased.

4. Aquifer Recharge - Clinton Lake stores about 75,000 acre feet of water. Certainly this aids in recharging existing aquifers.

5. Last, but not least, is the value of the site for recreation. The lake has been stocked with bluegill, redear sun fish, channel catfish, largemouth bass, sunshine bass, white bass, tiger musky and walleye. Boat launching ramps have been built and fishing will be permitted this August. Campgrounds, a marina, picnic sites, etc. will be constructed later.

The value of cooling lakes for wildlife and the environment is not just this utility employee's "propaganda". Doctors Bellrose, Larimone, and Tranquilli (Illinois Natural History Survey) have sent letters to Douglas Costle, of the Federal EPA, extolling the virtues of cooling lakes in Illinois.[2 & 3] These lakes are partially restoring aquatic habitat drained years ago for farming. There are some who say we will need the land occupied by cooling lakes for food. If so, Dr. Homer Buck (Illinois Natural History Survey) assures me a managed, thermally and nutrient enriched lake can produce much more protein per acre than the best field of soybeans.

LITERATURE CITED

FEPA, 1974. New Source Performance Standards - Guidelines and Standards for Electric Power Generation (40 CFR Part 423, Federal Register, October, 1974).

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[1] Personal letter from Dr. Paul Shildneck. His new species list paper will be in a forthcoming: Transaction - Illinois State Academy of Science.

[2] Dr. Frank Bellrose's letter to Douglas Costle (FEPA) dated January 5, 1979.

[3] Drs. Larimore & Tranquilli's letters to Douglas Costle (FEPA) dated January 12, 1979.

Wildlife Habitat Evaluation and Mitigation Analysis of a Proposed Power Plant Site[1]

Karen J. Miller, JoAnne Mensch Sorenson and Charles R. Hazel[2]

Abstract: Habitat Evaluation Procedures (HEP) devised by the USFWS were used in a joint effort by a utility company, consultant and agency biologists to quantify the nonmonetary value of wildlife habitats on a proposed power plant site in central California. Based on the evaluation, recommendations were made for mitigating losses of wetland habitats on the project site, with particular emphasis on *Salicornia* marshes inhabited by the endangered salt marsh harvest mouse.

INTRODUCTION

Pacific Gas and Electric Company (PG&E), a California utility, proposed to construct a coal-fired power plant at one of four locations in northern California. Before such a power plant can be constructed in California, the utility must follow a multi-step process to meet governmental requirements. The first step involves submitting what is called a Notice of Intention or NOI to the California Energy Commission for review. The NOI is a preliminary description of the proposed project and an environmental assessment of each alternative proposed site. Based on information in the NOI, the Energy Commission determines whether each proposed site is environmentally suitable for further study.

During the NOI stage, Jones & Stokes Associates, Inc., was hired by PG&E to do a preliminary assessment of biological resources on the four proposed sites (Jones & Stokes Associates, Inc. 1975; PG&E, 1977). Subsequent, more detailed studies undertaken by Dr. Howard Shellhammer of San Jose State University and others documented the presence of an endangered species, the salt marsh harvest mouse (*Reithrodontomys raviventris halicoetes*) on one site, known as the Montezuma site, which is located partially within brackish and freshwater wetlands of the Sacramento-San Joaquin Delta. The salt marsh harvest mouse was found to inhabit *Salicornia* or pickleweed marshes of the site (Envirodyne Engineers, 1978).

PG&E had prepared two alternative plant layouts for the Montezuma site. Alternative I involved placement of plant facilities in lowlands of the site, directly adjacent to the river delta. In Alternative II, most of the facilities were placed in upland habitat away from the river edge.

The Energy Commission reviewed the NOI for each proposed layout on the Montezuma site and concluded that both layouts had the potential for significant on-site adverse impact on *Salicornia* marsh habitat as well as other brackish and alkali wetlands important to waterfowl and shorebirds. The Energy Commission, however, was not able to accept or reject the Montezuma site as a potential power plant location because no information was available to the Commission on the magnitude of potential impacts on wetland habitats or the feasibility of mitigating or compensating for their losses. It also became apparent through discussions with concerned agencies that there was no clear consensus as to the value of these wetland habitats on-site. Both state and federal agencies are bound by laws and policies to protect significant wetlands and the habitats of rare and endangered species.

METHODOLOGY

Jones & Stokes Associates was retained by PG&E to study the question of habitat value and to determine if mitigation could be accomplished on the Montezuma site or would have to take place at an off-site location (Jones & Stokes Associates, 1978).

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Jones and Stokes Associates, Inc., Sacramento, California.

To answer these questions, the Habitat Evaluation Procedures (HEP) devised by the U. S. Fish and Wildlife Service (USFWS) were utilized (USFWS, 1976). HEP provides a way to quantify the value of wildlife habitat on a given site. Where alternative plant layouts had already been selected, as was the case for the Montezuma site, HEP could be used to quantify potential impacts on wildlife habitat and determine the amount of land or management required to mitigate habitat losses.

Because of great interest in the project by concerned agencies, the USFWS and California Department of Fish and Game were asked to participate in field evaluations. Two separate teams of biologists familiar with delta habitat conducted independent evaluations in October 1978. Each team consisted of a representative from each agency and consulting firm.

One to three sample sites within nine habitat types were evaluated by each team. Habitat types rated were: valley grassland, rotational cropland, seasonal pond, willow thicket, riparian shrubland, Eucalyptus grove, brackish marsh, alkali marsh and Salicornia marsh, with the last three habitat types considered to be of greatest concern.

Within each habitat type, each sample site was rated on a scale of 1 to 10 for its capacity to support up to 10 wildlife species known as Evaluation Elements. Representative species chosen were known from previous studies to be common resident or migrant species.

To reduce subjectivity of the ratings, each team of evaluators was given information on life requisites of each Evaluation Element and a set of written evaluation criteria. The final rating for each Evaluation Element at a sample site represented an average of the rating given by each team member. Merits and demerits of each site were discussed among team members so that a consensus of habitat value could be reached.

Through a series of calculations, the Habitat Unit Value (HUV) for each habitat on-site was determined from sample site ratings. The HUV, which is a number between 1 and 100, is a measure of the habitat's capacity to meet life requisites of each species evaluated and by extrapolation of all species supported by the habitat type. The HUV, when multiplied by the acreage of that habitat, yields total Habitat Units (HU) of a habitat type -- a measure of both quality and quantity.

Each evaluation team also determined management potentials for each habitat type. The management potential represents the maximum value that can be obtained for a habitat type through the use of management techniques for wetlands, such as water manipulation or planting preferred food species. The management potential as such is some number between 100 and the HUV just derived.

Impacts on wildlife habitat associated with the two alternative plant layouts were analyzed over the project life to calculate yearly losses of HU by habitat type. To adequately evaluate impacts several assumptions had to be made. These assumptions did not necessarily represent the actual course of events, but were necessary to analyze project impacts using HEP. These assumptions were:

1. All acreage of each habitat type covered by plant facilities would be totally lost for the life of the project.
2. Acreages of each habitat type on-site would not change appreciably in the future without the project.
3. The value of existing habitat types would not change in the future without the project.
4. There would be a zone of indirect effects from noise, human disturbance, etc., surrounding the plant site. The wildlife value of habitats in this zone would be reduced for the life of the project as agreed upon by the evaluation teams.

Given these assumptions, long-term changes in HU were estimated over the life of the project and expressed as annualized HU gains or losses. From this, in-kind compensation or replacement of lost habitat through improvement of like habitat was estimated using the following formula:

$$\frac{\text{Annualized HU Loss}}{\text{Management Potential - HUV}} = \text{Acres Compensation Required}$$

RESULTS AND DISCUSSION

Table 1 presents results of field evaluations for those habitat types considered of greatest concern on the Montezuma site. HUV and management potentials presented here represent an average of each evaluation team's results. HUVs calculated by each team were found to differ by less than 10%. Management potentials differed by only 6%.

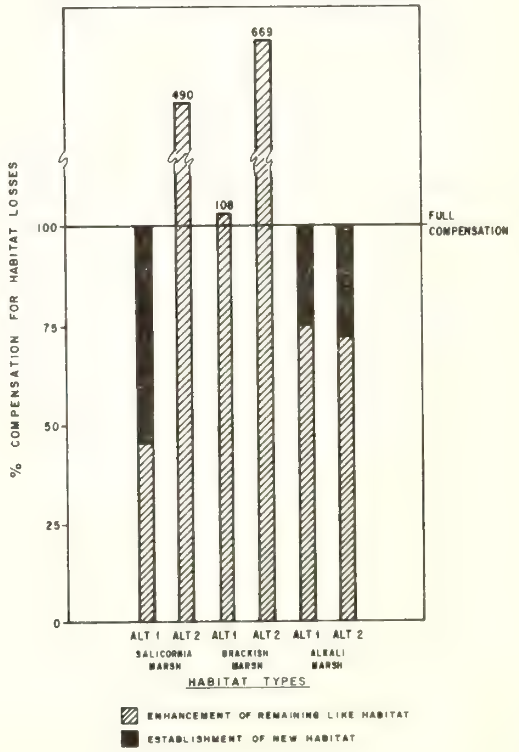
Table 1. Summary Comparsion of Project Impacts and Compensation Requirements

	Habitat Type			
	Salicornia Marsh	Brackish Marsh	Alkali Marsh	Wetlands Total Acreage
Present Acreage	71	30	32	133
HUV	58	79	53	-
Management Potential	75	91	83	-
		Alternative I		
Acreage Impacted	32	4	14	50
Annualized HU Loss	1,499	290	717	-
Acres Compensation Required	88	24	24	136
		Alternative II		
Acreage Impacted	13	1	16	30
Annualized HU Loss	208	52	665	-
Acres Compensation Required	12	4	22	38

A comparison of alternative plant layouts shows that Alternative I would have a greater impact on wetland habitat than Alternative II. Correspondingly, the acreage of undisturbed wetland habitat needed on-site to mitigate these losses would be approximately four times greater for Alternative I (136 acres versus 38 acres).

To determine if these compensation requirements could be accomplished on-site, acreages of undisturbed wetland habitats were multiplied by their management potentials to determine the HU that could be gained through habitat enhancement. Figure 1 graphically displays these results. Under Alternative I enhancement of undisturbed brackish marsh habitat to its management potential would fully compensate for project-caused losses. However, only 41% of Salicornia marsh and 75% of alkali marsh could be compensated through habitat enhancement. Under Alternative II, management of remaining brackish and Salicornia marsh habitat would more than compensate their losses, but only 72% of impacted alkali marsh habitat would be compensated through enhancement of like-habitat on-site.

FIGURE 1
POTENTIAL FOR ON-SITE COMPENSATION THROUGH A COMBINATION OF WETLAND HABITAT ENHANCEMENT & ESTABLISHMENT



To compensate for remaining wetland habitat value losses on-site not achieved by improvements through management, it was suggested that new habitat could potentially be established. To accomplish habitat establishment, the following facts had to be recognized and reconciled:

1. Management of *Salicornia* marsh exclusively for the salt marsh harvest mouse could reduce its value to other important wetland species.
2. Establishment of new wetland habitat would obviously result in a loss of other wildlife habitat types that also are valuable to wildlife.
3. There would be a time lag before maximum productivity of newly established wetlands would be realized.
4. There would have to be reasonable assurance that enhancement and establishment of wetland habitat, particularly in the case of the endangered salt marsh harvest mouse, would be feasible biologically and physically.

In reference to the last statement, several studies led by Dr. Shellhammer that deal with the feasibility of establishing new *Salicornia* marsh on the Montezuma site have recently been completed (Envirodyne Engineers, 1978; Biosystems Analysts, Inc., 1979). Results of these studies indicate that it should be feasible to establish additional salt marsh harvest mouse habitat on-site. By expanding existing *Salicornia* marshes, it is likely that resident mice, with time, would expand into this newly established habitat.

In addition to management of *Salicornia* marsh, a variety of techniques for enhancing or establishing brackish and alkali marsh habitat were discussed in our report to PG&E. Methods of avoiding disturbance to wetlands surrounding the plant site during the construction phase were also suggested.

CONCLUSION

In conclusion, it was found using HEP that on-site mitigation for project-caused wildlife habitat losses from either alternative plant layout should be possible by combining habitat enhancement and new habitat establishment. The Montezuma habitat evaluation provided one of the first occasions in which utility company biologists, consulting biologists and governmental agency biologists have jointly developed a quantitative data base for negotiating mitigation for project impacts.

As an outgrowth of this cooperative study, further joint site evaluations were undertaken using HEP base data. Important wetland habitats and their boundaries were carefully delineated. A third facility layout was developed that would avoid direct impacts on all wetland habitats.

Use of a quantitative approach to establishing site wildlife values resulte in a number of benefits: 1) information needed by the California Energy Commissio to evaluate viability of the site was provided, 2) the validity of the HEP approach was demonstrated through production of reasonable and replicable results, 3) data produced by this established evaluation system were considered more reliable by non-biologists, 4) it resulted in qualified biologists from the public and private sectors working together to establish a data base acceptable to all, 5) it resulted in an alternative facility layout that could avoid many of the direct biological impacts on habitats of concern, and 6) for whichever alternative facility layout chosen, the data exist to identify the wildlife values and habitats that need to be compensated.

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Can Coastal Power Stations be Designed to Offset Impacts by Habitat Enrichment?[1]

John S. Stephens, Jr. and John B. Palmer[2]

Abstract.--Coastal generating stations probably have only a minor detrimental effect upon coastal fishes. Studies of one coastal station in a small harbor situation indicate that the induced thermal stratification in the harbor has resulted in an increase in fish faunal richness. This result and additional considerations indicate that it may be possible to enhance coastal fish resources through construction of harbors with estuarine-type circulation driven by steam electric stations.

Most published research regarding the effects of power plant cooling systems on fishes have involved freshwater or enclosed bay habitats where the intakes and effluent impact heavily upon geographically restricted populations. Generating stations constructed along open coastal environments do not impact such populations. At least our present knowledge would suggest that coastal fishes of unstable substrate are rarely restricted to specific territories or areas, usually moving in search of food within the limits of their habitat tolerances (depth, temperature and substrate). Seasonal and/or life history related migrations also may occur. Such species are generally either diffuse or made up of numerous wandering schools with extensive geographical ranges. Both population size and entrapment significance is, therefore, difficult to determine. In southern California, most of these species occur at least throughout the bight (i.e. from Pt. Conception to Baja California).

Our four years of examination of fish entrapment in power plants (Johnson[3]) along this coast indicates that the majority of the species entrapped in significant numbers are wandering, schooling, shallow, littoral species. By contrast, observations around intakes suggest that reef species adapt as adults to intake structures with very limited entrapment and may even use intake currents as feeding stations (Helvey[3]). Entrapment is not a problem for adult resident species. Entrapment is highly species specific, strongly related to innate behavioral patterns, and is predictable. Similar data on fish eggs and larvae is beginning to be collected. Apparently, most early life history stages tend to orient to either the substrate or the surface layer, and mid-water intakes do not heavily entrain marine eggs and larvae. It appears, therefore, that entrapment in the open coastal environment is a manageable source of fish mortality, though occasional catastrophic events cannot be overlooked.

The effect of effluent discharge in the open coastal environment depends upon discharge temperature, change in temperature between effluent and receiving waters and associated water movement. Discharges can be designed to effect rapid mixing (diffusers) or to allow pods of warm, low density water to maintain their integrity during cooling. The former system would lay down an extensive area of mixed, warm thermal effluent while the latter would reduce the area but increase the temperature of the effluent. The detrimental effect of warm effluent in an open coastal situation is largely speculative. Assuming the discharge change in temperature is within existing legal limits and does not impinge heavily on intertidal communities, no effect should be noted on adult fishes as relatively few species actively inhabit the surface layer and these species are generally those which select warm water, are mobile and can avoid extreme conditions. The effect on larval fish and pelagic fish eggs is of more oncern. It seems probable to us that the ost effective protection for such stages is sharp density barrier. We have little oubt that fish eggs and larvae that enter bnormally warm thermal effluent would not urvive, but a sharp density barrier would ecrease the probability that such planktonic tages could enter warmed surface pods. urther, recent experiments in both horizontal nd vertical larval thermal preference experients (Shrode, pers. comm.) indicate that arval avoidance is by vertical rather than orizontal movement (down swimming). From hese data we suggest that relatively unmixed ffluent is probably less detrimental to arval fishes than diffused.

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[1] This paper presented at the Mitigation Symposium, July 16-20, 1979, Fort Collins, Colo.

[2] James Irvine Professor of Environmental Biology, Occidental College, Los Angeles, Calif. and Senior Research Scientist, South California Edison Co., Rosemead, Calif.

It is probable that antifouling techniques, .e. heat treatment and chlorination, could ave more of an effect on all stages than ormal operational activites. But these reatments are limited in time and would only mpact heavily on eggs and larvae during late pring and Summer.

From the above, it is suggested that pen coastal generating stations probably ave only a minor detrimental effect upon oastal fishes. Our studies of fish populaions in a semi-enclosed intake and discharge ystem at King Harbor, California, suggest ertain positive effects that can be engineered y modifying an open coastal system. King arbor is a small boat marina, formed entirely y a rocky breakwater on an open, sandy beach abitat. The horseshoe shaped harbor, located n a nearly north-south coastline, opens to he south. The mouth of the harbor is located t the termination of Redondo submarine anyon. The three intakes to Redondo steam enerating facility are located, one at the outh of the harbor in 6 m above the substrate hich is at a depth of 18 m, and two smaller tructures approximately in the middle of the arbor. All intakes have velocity caps esigned to produce horizontal flow. The hree discharges include a large vertically ischarging pipe about 100 m inshore from the arger intake and within the harbor, and two mall discharges outside and well to the orth of the harbor mouth. The result of the onfiguration of the harbor, the intake and ischarge system, and the proximity of the ubmarine canyon is a highly modified thermal nvironment (Stephens 1978). During most of he year, a well developed thermocline is resent and surface to bottom gradient ranges etween 6-13°C. Surface waters, including hermal effluent, range from 15-24°C and ottom waters at 11 m with the entrained anyon upwelling from 10-15°C.

The diversity of fishes at King Harbor s extremely high. More than 45 species occur as residents of the harbor, and more than 100 species have been observed during the study period (1974-79). Six hundred sixty-seven isobathic five minute transects swum during 1974-78 averaged 11.8 species and 238 individuals per transect at King Harbor. Comparative studies at Palos Verdes Peninsula, a rocky shore environment (8.1 species and 99.1 individuals); Santa Monica breakwater, a similar artificial breakwater (8.9 species, 110.0 individuals); and Catalina Island (10.9 species and 157 individuals) indicate the rich nature of the King Harbor fish fauna. All differences are significant at < .05 level of probability. These data were taken using isothermal techniques. If we consider the fish observed regardless of depth (all available temperatures) at a locality, the mean number of species at King Harbor (43.2) is more than double that at Palos Verdes (19.6) and Santa Monica (17.0). These fishes include both warm temperate (65%) and cool temperate (35%) species which co-occur in these thermally diverse waters. The high density of fish in the harbor reflects adequate food resources for many broadly overlapping food guilds (Stephens and Ellison 1977). Both the abundance and diversity of fish at King Harbor has remained stable throughout the five year study period, though the actors have changed with shifts in the success of individual species. Laboratory tests with local species (Ehrlich et al. 1979) have supported our field observations. Species can be catagorized by their behavior in a gradient tank as cool preferring, warm preferring, or thermally tolerant (Terry and Stephens 1976). The distributions of fish in the natural harbor thermal gradient agree with these catagorizations. These data support our concept that the diversity of fishes in the harbor reflects the induced ecotonal thermal regime created there by the power station. This effect was further documented in March-April 1977 when the station was shut down for an extended period. After shut down, the thermocline degenerated, less than 3° separated surface and bottom temperatures during shut down. Three days following re-initiation of station operation the thermocline (7°) had re-established. A fish survey just prior to onset of plant operation yielded just 23 species, a figure similar to those from adjacent habitats but significantly lower than any other records from King Harbor. The diversity of fish had returned to normal levels 60 days after re-establishment of a thermocline. The fishes missing during the shut down survey were primarily cold but also some warm preferring species. Further, almost all younger stages (larvae through early juveniles) prefer warmer temperature than the adults. This may be looked at as an adaptation for faster growth, enhanced food supply, and/or protection for young fishes. The thermal effluent along with insolation of quiet harbor back waters appears to make them ideal nursery areas for local species. The majority of the fishes in the proximal half of the harbor are juveniles and this nursery may serve as a source of recruitment to adjacent areas.

The Research and Development Department of Southern California Edison finds these results very interesting because they suggest a way in which coastal siting may be made attractive--not just tolerated--in our region. There are several reasons why we expect that coastal siting will be receiving more attention in southern California in the future. These reasons are: (1) increasing resistance to the consumptive use of inland fresh water for off-stream cooling; (2) significant fuel inefficiencies of off-stream cooling vs. coastal once-through cooling; (3) proximity of load center to coast; and (4) increasing difficulty of long transmission routing in inland desert and agricultural regions.

To be ready with options for consideration in the event of siting a major facility on the coast, the potential for enhancing the coastal marine habitat is an exciting possibility. Taking the above work as suggestive of fish habitat design criteria, we have investigated conceptually the prospect of designing a semi-closed harbor type system with circulation driven by the discharge of a steam electric power station. The oceanographic engineering problem is: can an estuarine type circulation (i.e., a surface outflow of bouyant warm water coupled to a bottom counter flow of denser cooler water) be established throughout an entire embayment system? As a first approximation we investigated a flow pattern which would be driven by a nominal 1000 Mw power station operating at $\Delta T = 20^\circ F$, with the additional constraint that the thermocline at the embayment entrance would be about $5^\circ F$ or more. Thus, along the entire margin of the embayment there would be established the thermal structure which we have shown should increase fish faunal richness.

Preliminary calculations on embayment configurations which meet these criteria indicate that we have considerable scope to play with. For instance, a 1000 Mw plant with an initial discharge velocity of 1-2 ft/sec could incorporate a meandering harbor channel on the order of 100 feet across by 30-40 feet deep. This channel could be up to seven miles in length!

It turns out, in fact, that the problem of establishing a stratified flow system to meet specified criteria is merely a matter of hydraulic engineering, and in itself offers no technical difficulties.

The problem now is to adequately specify the design criteria for a system that will enhance productivity of the marine biota. Before we can do this with complete technical confidence, there are a number of aspects which require further work: (1) Stephens has established that thermal enrichment will increase faunal diversity for adults and juveniles in King Harbor where this work was done. As there was cold water incursion from the head of the Redondo submarine canyon involved in this enrichment, how dependent are we on proximity to canyon heads for this type of effect? Both cold water and cold water fish could be supplied by the location. There are probably three other submarine canyons near which we might be able to site a power station on our coast. (2) Will increased or at least adequate benthic production occur to feed the increased diversity of fish--or can it be bioengineered? We are investigating (Straughan 1979) the benthic fauna in King Harbor, and in other embayment systems in southern California with varying degrees of forced flow. An increased circulation should deliver more food particles and benthic larvae per unit time so that there would be more benthic organisms settling and more food to feed them and, consequently, more for the fish to eat. The enrichment of benthic larvae with increased flow has been demonstrated in open coastal systems (Osman 1978) and placement of shell fish in increased flow situations is also a standard technique of aquaculture, so we feel that optimism is justifiable. (3) A further important question is whether or not such a system would also enhance spawning and nursery functions for fish and shellfish. There is fair reason for thinking that for some species this will be the case. There are several species where spawning success is probably related to available habitat and such habitat would be increased by the proposed embayment system. A further consideration in the utilization by larval fish of the upper heated water of an embayment is the question of whether the fish will maintain themselves in the embayment or be swept out to sea. This is a normal risk to which larval fishes are exposed in most estuaries, and to which such forms must be adapted. In addition to the comfort of this general argument, we are investigating larval density gradients within embayments. It appears that gradients in density do occur at least for some species and presumably these are maintained by larval behavior. Consequently we expect that a number of species will be able to utilize effectively the warmer upper layer.

Selection by larval and juvenile fish of warmer water than that chosen by adults suggests that these smaller forms would accumulate in the upper warm strata. Increased temperature implies increased growth rate if sufficient food is available. This aspect is difficult to address directly. However, Stephens' group is looking into feeding and thermal metabolic relations of several harbor species (Helly 1976, Gardiner and Shrode 1978, Ellison, Terry and Stephens 1979). We hope to reach a judgment on this question on the basis of the information that has resulted and will result from this work.

(4) An investigation sponsored by Edison of the oceanography of King Harbor has shown an unusual rate of nutrient regeneration (Kolpack 1979). This regeneration appears to have the potential to contribute to food webs, and is related to the incursion of oxygen rich canyon water over the bottom. With the full understanding of this process, it is possible that embayment criteria can be specified to augment nutrient regeneration. On the southern California coast, where fresh water flows to the embayment are strictly limited, such regeneration may be of positive resource value.

All of the above considerations will probably be resolved in favor of our ability to design embayments to enhance biotic resources. Such embayments also offer reasonable prospects for combination with multiple-use marinas.

There is a great demand for recreational boating facilities in our area. On this basis alone it is expected than an embayment would be attractive to a large segment of the public. A general concept of such an embayment is shown by Figure 1. This configuration utilizes a wide meandering channel in which the stratified flow would be established. The margins of the channel are blocks of boat docks with interspersed fishing piers. Bathing beaches could also be accomodated. The intake structure is located on the side of the embayment away from the harbor opening. A porous dyke design (Schrader and Ketschke 1978) is suggested as a possible way to virtually eliminate fish entrapment. A bypass discharge to the other side of the embayment may be necessary for diverting the discharge during biofouling control episodes. The power station could be set back from the shore as shown to allow for auto parking and recreational park areas.

In conclusion, the work that SCE has sponsored in King Harbor indicates that artificial embayments could be designed to enhance coastal biotic resources, especially for certain fisheries. An estuarine type circulation driven by power plant effluent could be established in these embayments. This man-made circulation would contribute to fish faunal diversity and fishery nursery functions. On balance, a significant enhancement of biotic resources is to be expected in open coast areas such as in southern California. Multiple use prospects for such embayments are good and, coupled with resource enhancement, should make coastal siting an attractive option for utility management to consider. We are pursuing several lines of investigation which will allow us to specify design criteria completely and begin a more detailed cost-use analysis of this concept.

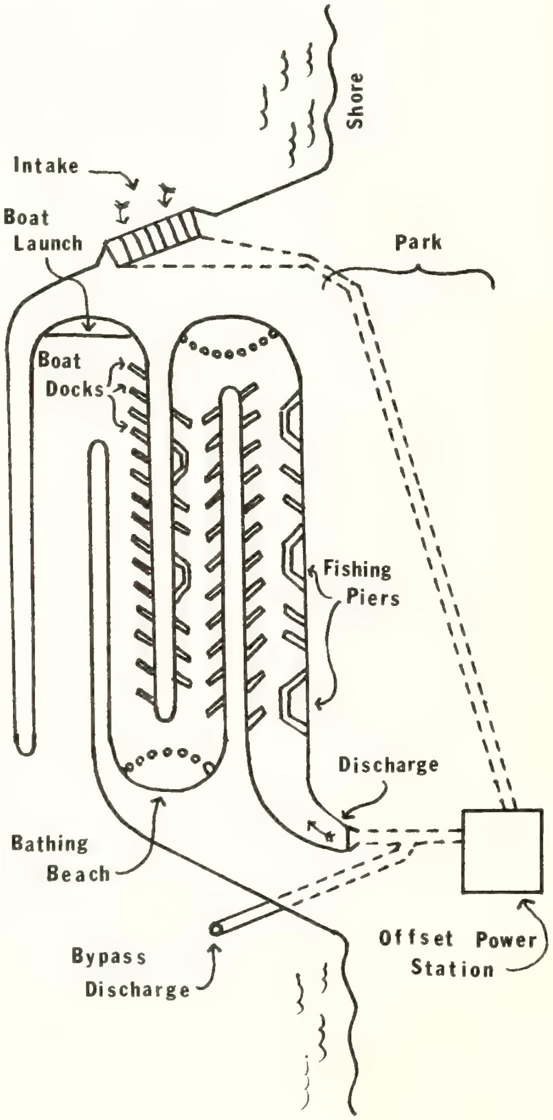

Figure 1.--Possible configuration of multiple use harbor with estuarine-type circulation driven by steam electric power station.

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Florida Power and Light Company and Endangered Species: Examples of Coexistence[1]

J. Ross Wilcox[2]

Florida Power & Light has interacted with nine rare and endangered species and, for the most part, we have experienced no direct conflicts. Animals involved are: the West Indian Manatee, the American Crocodile, the Southern Bald Eagle, three species of sea turtles, the American Alligator, the Indigo Snake, and the Everglade Kite.

The Company is documenting, through research and monitoring, ways in which endangered or threatened species can coexist with the production and transmission of electricity. Examples of this coexistence are presented and discussed.

INTRODUCTION

Florida Power & Light Company (FPL) is the sixth largest utility in the U. S. and has more than two million customers in a service area that covers approximately one-half the geographic area of Florida. Climates range from warm temperate to tropical.

More than 75% of FPL's generation output is used in residential communities in contrast to other areas of the country, where commercial customers dominate. We have summer and winter peaks that supply energy for cooling and heating. Within our service area, which encompasses all or part of 35 counties, FPL operates 10 power plants, having a total capacity of 11,000 MW. Power is distributed via 72,000 km of transmission lines with a maximum voltage of 500 KV. Approximately one-fifth of the generating capacity of the system is provided by nuclear energy with the balance being provided by oil and natural gas. FPL does not burn coal, but has announced plans to build two coal-fired units in the 1980's.

The Company owns and manages large tracts of land in both rural and urban areas. Much of this land is undeveloped and is used as a buffer zone to isolate power plants from residential and agricultural areas. These buffer zones serve as wildlife habitat for many species, both common and endangered, and place FPL in the wildlife business.

To date, FPL has interacted with nine rare and endangered species on the federal list and, for the most part, we have experienced no direct conflicts. Six endangered species include the West Indian Manatee, the American Crocodile, the Southern Bald Eagle, the Green Turtle, the Leatherback Turtle, and the Everglade Kite. Three threatened species include the Loggerhead Turtle, the American Alligator, and the Indigo Snake.

In the sense of stewardship and good business practice, the Company is documenting, through research and monitoring, that the production and transmission of electricity and the well-being of endangered species are compatible. Where real or potential conflicts are identified, FPL has taken positive actions to eliminate or minimize adverse consequences.

In this paper, the interaction of FPL with several of these rare and endangered species will be reviewed and our compatibility discussed.

WEST INDIAN MANATEE

The West Indian Manatee, or sea cow, is

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

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an air-breathing, aquatic herbivore that attains lengths of 3.5 m and weights of 1,000 kg. The endangered manatee is found in shallow coastal waters, bays, lagoons, estuaries, rivers and inland lakes of tropical and subtropical Central and North America. In the U. S., its present-day distribution is limited to peninsular Florida during the winter and isolated individuals are found in Texas and the Carolinas during the summer. Manatee population numbers are estimated at 1,000.

The manatee is a slow swimmer, but is capable of quick and swift movements for short distances. The animal is harmless and has no natural predators. In recent years, human activity has been identified as the largest cause of manatee injury and mortality.

One interesting feature of their behavior is that they seek warm-water refugia in Florida during the winter months. There is no such attraction during the spring, summer and fall months. Historically, the animals have congregated around constant-temperature freshwater springs but, with the population build-up of Florida and tapping of aquifers for agricultural purposes, many of these natural springs are not flowing today. What the manatees have done is to seek out industrial warm-water effluents as warm-water refugia. FPL has five plants that operate in a once-through cooling mode and, by contracting Florida Audubon Society to conduct a year-round aerial census program for us, we have documented these winter congregations, which are nothing but impressive.

Maximum numbers counted at our Fort Myers Plant located on the west coast during the 1978-1979 winter season were 265. During and after the passage of cold fronts where air temperatures may be as low as 0^{0} C, the animals are literally stacked up like cord wood in certain stretches of a river receiving our warm-water effluent. At our Port Everglades Plant located in the busy port of Fort Lauderdale, maximum numbers of manatees counted in our discharge were 114. At a nearby facility, the Lauderdale Plant, the maximum count was 36. Further up the east coast, our Riviera Plant in West Palm Beach had a maximum winter congregation of 68. Again, this facility is located in a busy port and the intracoastal waterway is very close to our discharge. The Canaveral Plant, located in the east-central part of the State, had 85 manatees as a maximum number. Summing all these numbers from the five plants, the total is 568 manatees out of an approximate population of 1,000. Thus, over the course of a winter, approximately 60% of the population of an endangered species is congregated around FPL plants, creating a potential of a mass disaster. These congregations are a very dynamic phenomena because some animals only arrive during the brunt of a cold front and quickly disperse to feed when the air temperature warms. Other animals are much more leisurely about leaving the effluent after a cold-front passage.

FPL is working very hard to promote a stewardship with these endangered animals. Through the efforts of the Aerial Census Program, Florida Audubon Society was able to collect scientifically valid data which was presented to the Florida Legislature and was the impetus for the passage of the Florida Manatee Sanctuary Act of 1978. This Act provides for the regulation of boat speed in 13 manatee congregation areas between November 15 and March 31st of each year.

One of the identifiable causes of manatee mortality and injury is collisions with boats. All adult manatees bear some type of scar resulting from contacts with high-speed motor boats. Manatees can easily avoid slow boats, and control of motor-boat speeds in these winter congregation areas, where large numbers of manatees gather, is an effective means of protecting the species. The speed zone signs with the effect of law, as stipulated in the Florida Manatee Sanctuary Act, will be in place by fall of 1979. All of the warm-water discharges of the five FPL plants noted previously are slated to have speed zones.

The Company has also contracted with the Florida Audubon Society to conduct a Public Awareness Program for manatees. By promoting an awareness for manatees, FPL, federal, state and local authorities are working to minimize human/manatee confrontations. Activities authorized include the production of TV and radio public service announcements, teacher training workshops, public speaking programs, articles for popular magazines, rental of outdoor billboards, placement of speed limit signs at five FPL plants, participation in radio and TV talk shows, and production of movies and filmstrips. The public speaking program has been very popular, especially during the winter months.

AMERICAN CROCODILE

The endangered American Crocodile ranges in length from 23 cm at hatching to 4.6 m for the larger males. The crocodile, in contrast to the more common alligator, is a slimmer animal with a longer tapering snout. Present population numbers are estimated at 200-400 individuals with approximately 25 breeding females.

Historically, the animal occurred in coastal swamps of southern Florida and Central America. Present-day distribution in Florida is restricted to the extreme southern tip of peninsular Florida, and to the northern portions of the Florida Keys. The Florida population is the only group of crocodiles in the continental U. S. Recent surveys have also documented that, in addition to occupying coastal mangrove swamps, brackish and salt-water bays, crocodiles will preferentially seek out abandoned coastal canals and rock pits for resting and reproduction.

Adults have no known natural predators, but eggs are taken by racoons and hatchlings suffer mortality from large wading birds. Adults wander during the non-breeding season, probably as a result of changing environmental conditions and food supply. The primary food of adults and subadults is fish, while juveniles feed on a variety of aquatic animals.

FPL owns approximately 8,900 hectares of land in the extreme tip of south Florida, all of which fall within the critical habitat of the crocodile. Approximately half of the area comprises the Turkey Point Plant and Site, which has an elaborate set of closed-circuit cooling canals for the condensers. The other half of the land is undeveloped at the present.

In 1977, we first discovered that at least one crocodile was living in the southwest section of the cooling canal system at Turkey Point. We began a survey which documented that there is a dynamic but rather extensive population of crocodiles at our Turkey Point Site. The adult population segment contains one large male and at least three breeding females. There are also six subadults that range in size from 0.9 - 1.8 m, as well as two yearlings that are about 0.6 m in length. Our consultants have documented in the 1978 nesting season that at least two nests were laid on the berms of the cooling canal system. These nests produced at least 18 hatchlings,which were captured, marked, and released. Several hatchlings were repeatedly recaptured over a year's period and allowed us to construct a growth curve. Several of the adults are fitted with radio telemetry collars, which have been very useful in tracking them and in locating nesting sites.

One of the most interesting facets of this program, is the confirmation that the crocodiles will preferentially seek out and utilize man-made canals and berms for resting and reproduction. The animals are almost in a controlled experiment because adjacent to the Turkey Point Site is approximately the same amount of area which is "prime habitat." Our studies have shown that the animals do not utilize this "prime habitat", but instead utilize a disturbed habitat.

We have also documented the presence of a crocodile at our Lauderdale Plant. This site is located in an urbanized and developed area of Fort Lauderdale. The plant was built in the 1930's and has approximately 400 hectares of cooling canals and buffer zone around it. The site contains two oil-fired units and 24 gas turbines, and it is located directly on the approach to the Fort Lauderdale International Airport.

As an offshot of the Manatee Aerial Census Program, an adult crocodile was seen twice over a six-month period in the cooling canal system of the Lauderdale Plant. With this knowledge, FPL, Fish and Wildlife Service, and the Florida Game and Fresh Water Fish Commission, released a maverick female crocodile at this site.

The introduction was successful and the female is still in the area. The other crocodile was not so lucky and was shot by someone trespassing on our property. Law enforcement of the Fish and Wildlife Service were called in to investigate, but could not make a case. This area is now legally posted. The unfortunate part of the whole incident was that the shot animal was a male, and we could have had the potential of a breeding pair.

SOUTHERN BALD EAGLE

A viable population of the Southern Bald Eagle, endangered on the federal level and threatened on the state level, exists in Florida with approximately 325 breeding pairs. Historically, the species was ubiquitous in Florida nesting in the Florida Keys, along the State's entire coastline, and near lakes and rivers throughout the interior. However, the population has declined over the last 30 years due to loss of nesting habitat and use of persistent pesticides.

FPL is developing a major power plant complex on a large tract of land in south-central Florida. Presently completed is a 3,200 hectare reservoir and two units are under construction with two more planned.

In 1971, as part of the Company's commitment to coexist with wildlife, a 160 hectare tract of land with a unique Cypress Tree strand was preserved by redesigning the reservoir around this area. Located in this strand is a Southern Bald Eagle's nest. A pair of eagles was active each nesting season from 1976 through the present when reservoir and plant construction were underway. The pair was successful the first two years, but was not successful this last breeding season. The nest is approximately 4 km from the plant construction zone. The adults actively fish the reservoir which contains large populations of fishes, and an immature eagle, probably from the 1976-1977 nesting season, is frequently seen roosting next to the reservoir.

Through environmental surveillance, we discovered that a pair of eagles was nesting on Company property near our Sanford Plant located in central Florida. Of particular interest is that the nest is approximately 0.8 km from the stacks and about 50 m from a 240 KV line. The adults were successful with two young being produced and fledged in 1979. The nest is near an active railroad line, is within hearing distance of a state highway, and is on an approach to the Orlando Airport.

We have advised plant, construction, and security personnel of the eagle's presence at each site and advised them to not disturb the animals. One key FPL person is very proud of his pair of eagles at his site and is very protective of them.

SEA TURTLES

Three species of sea turtles--the endangered Atlantic Green Turtle, the endangered Atlantic Leatherback Turtle, and the threatened Atlantic Loggerhead Turtle--all nest on the beaches of eastern Florida. During the months of May through August, the female turtle emerges at night from the sea to deposit eggs in a nest excavated on the beach. Each female exhibits up to seven egg-laying excursions during a nesting season. Approximately 70-130 eggs are laid and require about 60 days for incubation. The hatchlings emerge from the nest at night and return to the water.

FPL has an operational nuclear plant and sister unit under construction on a coastal site of mid-central Florida. The plant cools its condensers in a once-through mode, using an ocean intake and an ocean discharge. FPL owns approximately 500 hectares of land on the coast encompassing more than 4 km of pristine beach, which is ideal for turtle nesting.

Environmental monitoring has documented that three species of sea turtles nest on beaches owned by FPL, with the Loggerhead nests being the most numerous followed by the Green and then the Leatherback. Surveys conducted every other year since 1971 have not attributed any permanent decline in nesting frequency to plant effects. There was, however, a localized decrease in nesting frequency due to installation of the ocean intake and discharge pipes. Nests that were located by the construction zone and in immediate danger were relocated. Once construction activities had been completed, nesting frequency returned to that of control areas.

When a female emerges from the sea to nest, she is very sensitive to human disturbances, which may deter her from nesting that night. This is called a false-crawl and it is becoming more common in areas where beach development is occurring. Also of importance is the visual cue turtle hatchlings receive when they emerge from the nest at night. If the skyshine over the land area is greater than over the water, the hatchlings will crawl toward land instead of towards water and perish. Thus, it is paramount that human disturbance and night skyshine be minimized.

Because FPL owns 4 km of beach and will use it as a buffer zone for this nuclear plant, sea turtles will be guaranteed an undeveloped stretch of prime nesting beach for at least the next 40 years. To minimize the effect of skyshine on turtle hatchling behavior, FPL has placed reflector shields on security lighting and has planted a light screen immediately behind the beach dune to minimize misorientation of the hatchlings.

CONCLUSIONS

As I have documented with these examples, FPL can coexist with many endangered species. Large buffer zones owned by FPL in both urban and rural areas attract numerous species of wildlife, both common and endangered, placing FPL in the wildlife business. Some rare and endangered species inhabit these buffer zones for all or part of their life cycle and readily adapt. Thus, FPL does not need to take any special precautions other than just be aware of their presence. In other instances, when real or potential conflicts have been identified through research and monitoring, the Company has taken positive actions to eliminate or minimize any adverse consequences. Thus, in the sense of stewardship and good business practice (i.e., to avoid costly delays in permitting and construction), FPL is striving to demonstrate that the production and transmission of electricity and the well-being of rare and endangered species can be compatible.

Some Positive Aspects of Electric Utilities and Fish and Wildlife Resources[1]

Richard S. Thorsell[2]

Abstract - In the U.S., fish and wildlife issues usually are addressed in the planning process for new facilities required by the electric power industry. Many other issues must be balanced in the process. A survey demonstrates many forms of fish and wildlife can cohabitate and indeed be attracted to electric utility facilities. This implies negativism. Positive impacts should be acknowledged and credited to projects.

This paper will confine itself to he part of the electric utility ndustry, responsible for the generaion, transmission and distribution of lectric energy to the American ustomer.

This industry, for the most art, is investor-owned, highly egulated and franchised to provide public service. To put this in erspective about 77 percent of the enerating capacity in the country is nvestor-owned and serves approximatey the same percentage of the electric ustomers. This symposium will devote uch attention to government-owned art of the industry, and concern tself with large public works proects.

The electric utility industry's business is converting energy. he power of falling water, the power ound in the fossil-fuels, gas, etroleum, and coal -- and the energy ocked within the atom are the chief aw materials. We convert these aterials into a secondary form of nergy -- electricity -- available on emand in the quantity desired at the oint of use. We convert this energy hrough generators and transmit it by re. As a regulated industry, we are bligated to produce and deliver electricity with a high degree of reliability at the lowest possible cost.

The design and planning process in any major generation or transmission facility requires a great deal of public scrutiny and protection. An examination of a number of the environmental impact statements required for these facilities today will demonstrate readily that anywhere from 50 to 70 or more permits are required from agencies of the federal government as well as from the local sheriff (for permission to move heavy equipment on public roads).

Protection is afforded to fish and wildlife resources by a number of state and federal regulations such as the National Environmental Protection Act, the Federal Water Pollution Control Act and many specific fish and wildlife protective regulations.

In 1976, the Edison Electric Institute's Environment and Energy Committee's Land-Use/Environmental Impact Statement (EIS) Subcommittee recommended formation of a special task force to undertake a study of the "Compatibility of Fish, Wildlife and Floral Resources with Electric Power Facilities." The purpose of the proposed task force was to prepare, transmit and analyze the results of a questionnaire for a survey of electric companies in an effort to determine the positive extent of electric utility facilities on fish, wildlife

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Paper presented at The Mitigation Symposium, ly 16 - 20, 1979, Colorado State University, rt Collins, Colorado.

Environmental Projects Manager, Edison ectric Institute, Washington, D.C.

and floral resources. A particular emphasis of the study would have been on effects resulting from actions undertaken at the initiative of the utilities and from unanticipated and voluntary use of utility facilities by wildlife instead of regulatory requirements. Resulting information was provided to the industry, regulatory agencies and the general public. The study was taken as a voluntary effort in the public interest.

I. SPECIFIC TASK FORCE OBJECTIVES:

1. To survey the electric utility industry to document existing fish, wildlife and floral management programs and studies.

2. To survey and document voluntary use of electric utility industry facilities by fish, wildlife and floral resources.

3. To describe the compatibility of these resources with electric power facilities, based on summarization of existing data.

4. To facilitate the gathering of similar types of information required by the Electric Power Research Institute and the U.S. Fish and Wildlife Service.

5. To report results to the EEI Land Use/EIS Subcommittee.

In the summer of 1976, the Task Force on Compatibility of Fish, Wildlife and Floral Resources with Electric Power Facilities was formed. In November 1976, the electric power industry was surveyed to determine specific effects of fish, wildlife and floral resource managment programs. Four distinct categories of power facilities were addressed in the questionnaire:

Transmission/Distribution Rights-of-Way;
Power Plant Sites
Hydroelectric Facilities and Miscellaneous Areas.

For each category, information was sought on the following:

1. Studies conducted commissioned o participated in by the companies a related to fish, wildlife and vegetation.

2. Management programs conducted commissioned or participated in by th companies as related to fish, wildlif and vegetation.

3. Voluntary use of utility facilities by fish, wildlife and flora resources.

The task force was composed of th following individuals:

Wendell E. Smith (Chairman), Idah Power Company; Milton R. Anderson, Ne England Electric System; Stephen R Berguson, Minnesota Power and Ligh Company; Edward W. Colson, Pacific Ga and Electric Company; Richard L Morgan, Jr., Tennessee Valley Authority; Al B. Rodney, Public Servic Company of New Mexico; Bobby J. Ward Carolina Power and Light Compan and Richard S. Thorsell, Ediso Electric Institute.

II. SUMMARY OF TASK FORCE FINDINGS

A. GENERAL

112 electric utilities responded t the survey questionnaire - thes companies provide more than 7 percent of the electric power sold i the United States.
96 electric utilities reported activities.
70 have conducted studies.
83 have management programs.
50 have observed voluntary uses.

B. TRANSMISSION AND DISTRIBUTION SYSTEMS

70 utilities reported activities.
34 companies have conducted studies.
52 companies have management programs.
36 companies reported voluntary utilization or benefits of their facilities.

C. POWER PLANT SITES

72 utilities reported activities.
52 companies have done studies.

15 companies have management programs.
3 companies have observed voluntary
se of facilities.

. HYDROELECTRIC FACILITIES

9 utilities reported activities
5 companies have conducted
8 companies have management programs.
companies reported voluntary use of acilities.

. MISCELLANEOUS

2 utilities reported activities.
0 companies have conducted studies.
9 companies have management programs.
companies have observed voluntary ctivities.

. THREATENED AND ENDANGERED SPECIES

eventeen companies reported they are nvolved in studying, protecting or anaging endangered species. A few pecies, such as bald eagles, are on e federal endangered species list; ny other species reported are on the ate lists.

SPECIAL LAND DESIGNATIONS

venty-seven companies have engaged in pecial land-uses or have designated nds for specific purposes. Power oject lands have been transferred or ased to agencies, usually at the ate level, for such things as ldlife refuges, natural areas, parks d fish hatcheries. In addition many mpanies have set aside lands to eserve or protect natural features d unique flora or fauna.

. SURVEY METHODS

To determine accurately and cument what power utilities are ing relative to fish, wildlife and oral resources, the task force epared and distributed the questionire and compiled results. The task rce was interested in documenting e types of studies being conducted commissioned voluntarily by power npanies. Generally, preconstruction or operational studies or monitoring activities required by regulatory agencies were not requested in the questionnaire. Respondents were asked to specify if studies had already been conducted, were under way, or were planned for the future. Companies also were requested to submit copies of reports where possible.

The task force also wanted to determine resource management programs initiated by the utility industry and further plans of companies to provide management techniques for fish, wildlife and floral resources.

An important objective of the questionnaire was to have companies report voluntary or unanticipated uses of their facilities or lands by fish, wildlife or floral resources. Observations of such uses have led to studies or management programs in the past. It was hoped the compilation of voluntary uses would be helpful to biologists of other utilities and would provide an indication of the positive impacts of power facilities in terms of fish, wildlife and floral resources.

The questionnaire was distributed to chief executives of utilities by the Edison Electric Institute. Responses to the questionnaire were prepared by a variety of company personnel, including biologists, engineers and company managers.

IV. CONCLUSIONS

Based on the analysis of the survey conducted by this Task Force, it is apparent the electric utility industry is vitally concerned with flora and fauna on project sites or attracted to power facilities. The industry has conducted numerous studies and initiated management programs to protect and enhance the fish, wildlife and floral resources.

The industry has initiated numerous studies. These studies have contributed to the latest knowledge of specific biological problems or management opportunities. A number of excellent reference materials have resulted from these activities. In the course of these studies, the academic community has benefited through grants and employment of students in productive and educational endeavors.

Management programs have resulted in increased productivity of fish, wildlife and floral resources on a consumpive and noncomsumptive basis. Associated recreational benefits, such as fishing, hunting and wildlife observation, have resulted from power projects. Unique biological communities have been set aside for preservation; threatened and endangered species have been identified and protected; and lands have been given or licensed to state agencies to provide fish, wildlife and recreational benefits for the public.

Many unanticipated positive relationships through voluntary use of power facilities by flora and fauna resources have been reported for all categories. Examples such as raptor use of power poles and transmission towers as nesting and roosting sites, are numerous. Waterfowl, shorebirds, fish and endangered species are commonly identified and asociated with power plant facilities and operation. In several instances these voluntary uses have led to studies and management programs by the power companies.

Based on preliminary evidence received, it has been compatibility exists between fish, wildlife and floral resources and electric power facilities.

A detailed summary of the study - Preliminary Report - Compatibility of Fish, Wildlife and Floral Resources with Electric Power Facilities is available from the author at the Edison Electric Institute, 1111 19th Street, N.W., Washington, D.C. 20036.

The survey presently is being updated, and the Urban Wildlife Research Center, Inc. has been retained to annotate the material and prepare a summary report.

Many major projects are usually viewed from the aspect of fish and wildlife detriment. The type of study illustrated by this paper, however indicates more effort should be devoted to anticipation and identification of positive impacts on fish and wildlife resources from major electrical industry projects.

Response of Sage Grouse to Artificially Created Display Ground[1]

James Tate, Jr. [2]
Mark S. Boyce [3]
T. R. Smith [4]

An artificially prepared display ground for Sage Grouse was chosen to compare favorably with vegetational and physiognomic parameters determined for several nearby traditional display grounds. In the face of impending development the traditional display ground was destroyed. Visitations to the artificial lek were few. Visitations by both sexes and copulations increased on a nearby satellite display ground monitored both in 1978 and 1979.

INTRODUCTION

In 1978 Atlantic Richfield Company con- acted with the second author to conduct a ge Grouse mitigation study. At the company's al Creek lease approximately 40 km south of llette, Campbell Co., WY., a Sage Grouse rutting ground (lek) fell within the rail- ad loop and adjacent to the secondary crush- for a planned surface coal mine.

A study plan was devised to:

1. Select and prepare an artificial ternate lek site to attract birds displaced om the primary strutting ground (Sec. 17, 6N, R70W).

2. Determine pre-disturbance distri- tion and density of sage grouse on the study ea.

3. Capture, tag, and radio-equip a representative sample of the local sage grouse population for monitoring its response, e.g., reproductive behavior, success and movements, to disturbance of the primary strutting ground.

4. Deter the use of the primary strutting ground by the local sage grouse population.

Methods

Display Ground Observations

Observations of breeding birds were conducted at the strutting grounds: A. Section 17 lek; B. Section 18 satellite lek; C.Hoadley Road lek. Locations are shown in Figure 1. The Section 18 and Hoadley Road leks were observed irregularly from a vehicle. Primary emphasis was given the Section 17 lek where observations were conducted from either a blind located approximately 30 m east of the mating center, or a vehicle.

All observations were made with 7 x 35mm binoculars or a 20x spotting scope. Data collected included: numbers of males and females, number of marked grouse, number of copulations, and times of bird's departures.

---

[1] Paper presented at The Mitigation Sympo- um, Colorado State University, Ft. Collins, ., July 16-20, 1979.

[2] Principal Environmental Coordinator, lantic Richfield Company, Denver.

[3] Assistant Professor of Zoology, Uni- rsity of Wyoming, Laramie.

[4] Research Assistant, University of Wyo- ng, Laramie.

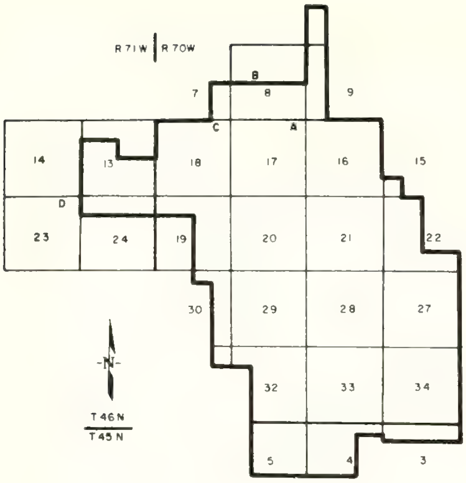

Figure 1.--The Coal Creek permit area with Sage Grouse Strutting Ground (lek) locations. A. Sec. 17 lek destroyed during mine development; B. Alternate lek artificially created; C. Sec. 18 satellite lek; D. Hoadley Road lek.

Capture and Marking

Birds were captured by spot lighting individual birds, cannon-netting of the Sec. 17 lek and netting of females on the nest or with a brood. Solar-powered radios were placed on some birds using backpack harnesses. All captured birds were outfitted with patagial tags or ponchos in distinctive color and number combinations. Birds were leg banded with Wyoming Game and Fish Department bands.

Preparation of the alternate lek site

Based on criteria outlined by Rothenmaier (1979) a site in the SE1/4NW1/4 of Sec.8, T46N, R70W was selected for establishing the alternate lek (location B, Figure 1). This site occurs in a broad valley floor approximately 1.5 km NNW of the Section 17 lek and is characterized by moderate sage brush (Artemisia tridentata) cover, and gentle topography.

Preparation of the site to attract sage grouse included clearing the site of sagebrush cover and equipping it with decoys and a sound system for playback of sounds of a sage grouse lek. Decoys were constructed of papier-mache following a technique utilized by taxidermists to construct large mammal forms.

The sound system consisted of an auto cassette tape player, a 36-watt power booster, two 8-inch, all-weather horn speakers, a 12-hour timer and a 12-volt automobile battery power source. A recording of sounds of a sage grouse display ground was obtained from the Cornell Laboratory of Ornithology, and duplicated in a continuous play cassette tape.

On March 16, a circular area of approximately 0.27 ha was cleared of sagebrush with a backhoe, leaving the topsoil undisturbed. The following day 19 (8 male and 11 female) decoys were placed on the opening and the sound system set up along a fence adjacent to it. The sound system was set to play from 0500-0700 hours and 1700-1900 hours.

RESULTS

The strutting ground counts are detailed in Figures 2-5. In 1978, a few birds were observed on the Sec. 18 satellite strutting ground during the peak strutting period. A male attendance of 5.7 occurred on only 6 days in late March and early April. Females were seen on the Sec. 18 lek on only two days in 1978; 12 hens on 31 March and one hen on 2 April 1978. All other observations reported for 1978 occurred on the principal Sec. 17 lek (Fig.2).

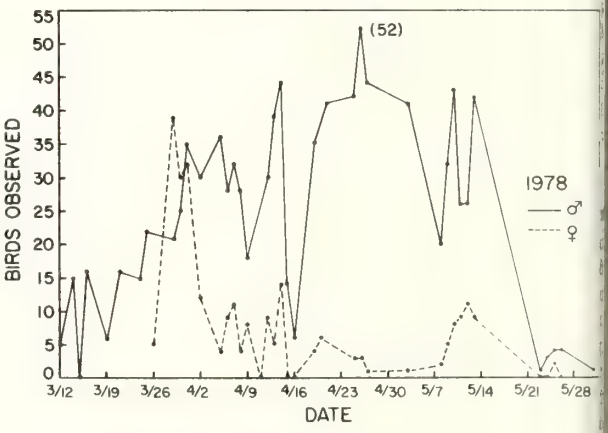

Figure 2.--Number of male and female sage grouse observed on the Sec. 17 and Sec. 18 strutting grounds in 1978.

The combined counts from the Sections 17 and 18 strutting grounds for 1978 and 1979 can be compared in Figures 2 and 3. Although the counts exhibit similar seasonal distributions in both years, it appears that the counts average lower in 1979 than in 1978. We tested this hypothesis by comparing individual male counts in 1979 with a moving 3-day average of the counts from 1978. We scored each count as falling above or below expected in 1979 and discovered significantly ($X^2 = 18.75$, P 0.005) smaller male counts in 1979 than in 1978.

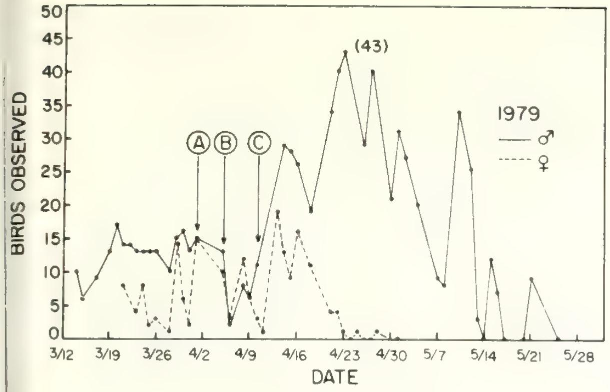

Figure 3.--Number of male and female sage grouse observed on the Sec. 17 and Sec. 18 strutting grounds in 1979. The Sec. 17 lek was cannon-netted at point A. The vegetation on the Sec. 17 strutting ground was partially removed at point B, and the lek site was totally destroyed at point C.

During March and April both male and female sage grouse were concentrated around the strutting grounds in Sec. 17 and Sec. 18. During early May, males continued strutting and their distribution was restricted to immediate vicinities of the strutting grounds. By late May, male visitation to the strutting grounds was greatly reduced, and based on the movements of radio-telemetered males on 25, 26 and 27 May, adult males began to disperse from the vicinities of strutting grounds at this time.

On 5 April 1979, the primary portion of he Sec. 17 strutting ground on which strutting ctivity had been concentrated was turned over ith heavy machinery and pushed into large ounds. Prior to this date (19 March - 5 April) ounts of male sage grouse on this strutting round had become relatively constant ranging rom 10 to 17 ($\bar{x}$=13.6) (Figure 4). Female isitation had shown greater fluctuations in n increasing trend from 4 hens on 23 March hen visitation began to 15 on 1 April ($\bar{x}$=4) hen a peak count occurred and a gradual decline egan (Fig. 5).

During the pre-disturbance period, counts n the Sec. 18 "satellite" strutting ground howed very little use by the sage grouse population. One male was observed on two occasions etween 22 March and 5 April (Fig. 4) while hen ounts fluctuated from 8 on 21 March to 0 on April ($\bar{x}$=3.2) (Fig. 5). These findings were imilar to those for 1978 when the Sec. 18 trutting ground received only limited use by he sage grouse population.

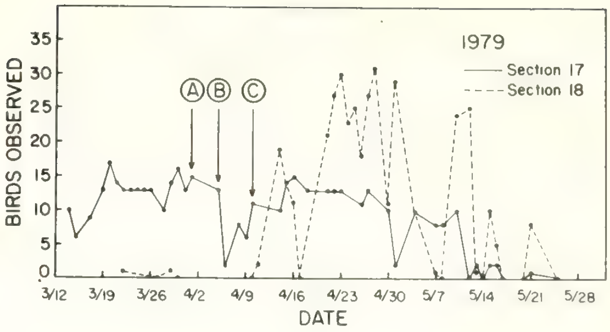

Figure 4.--Number of male sage grouse counted on the Sec. 17 and Sec. 18 strutting grounds in 1979. Strutting ground disturbances occurred at points A, B, and C, as detailed in the caption to Fig. 3.

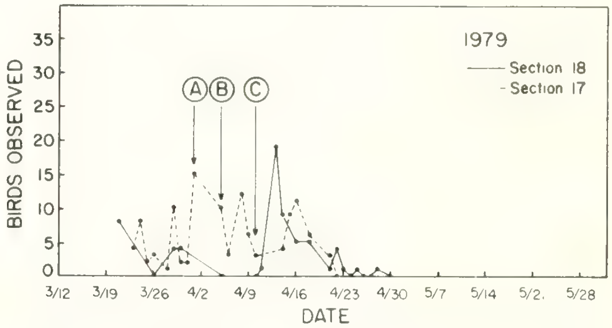

Figure 5.--Number of female sage grouse counted on the Sec. 17 and Sec. 18 strutting grounds in 1979. Strutting ground disturbances occurred at points A, B, and C, as detailed in the caption to Fig. 3.

Preparation of the artificial lek site ocated in the SE1/4NW1/4 of Section 8 was ompleted on 17 March, and this site was monitored in conjunction with the Sec. 17 and Sec. 18 strutting grounds. During the pre-disturbance period one observation of male sage grouse occurred on 23 March.

Following the initial disturbance of the Sec. 17 strutting ground, male visitations to this ground fell off markedly, but then gradually increased until counts approximated those of the pre-disturbance period. This stabilization occurred about 5 days after the initial disturbance and was not altered by the secondary disturbance on 10 April when the remaining portion of the Sec. 17 strutting ground, to which the sage grouse had since moved their strutting activities, was destroyed. Taking the highest of each group of three consecutive counts, the number of males visiting the Sec. 17 strutting ground ranged from 11 to 15 ($\bar{x}$=13) between 10 April and 10 May at which point visitation sharply declined until the cessation of strutting on 25 May.

In the period between the initial disturbance of the Sec. 17 strutting ground (5 April) and the secondary disturbance (10 April), no sage grouse were observed on the Sec. 18 satellite strutting ground (Figs. 4 and 5). However, immediately following the secondary disturbance, a portion of the sage grouse population shifted strutting activities from the Sec. 17 strutting ground to the Sec. 18 strutting ground as male and female counts on the latter increased to 19 and 19 respectively within 4 days (Figs. 4 and 5). This shift was confirmed by the observation of two birds (1 male and 1 female) on the Sec. 18 lek which had been captured and tagged on the Sec. 17 lek.

Throughout late April and early May, cock counts on the Sec. 18 strutting ground increased and peaked while those on the Sec. 17 strutting ground had stabilized. Using the highest of each set of 3 consecutive counts, male visitation on the Sec. 18 strutting ground ranged from 14 to 31 birds ($\bar{x}$=25) between 14 April and 12 May at which time counts declined rapidly until no observations occurred after 25 May (Fig.4).

The disturbances to the sage grouse lek may also have accounted for the lack of an abrupt peak in hen visitation during the strutting season of 1979 as occurred in 1978 (Figs. 2 and 3) and presented an erroneous picture of female density. While the peak in hen attendance on the study area (Sec. 17 and Sec. 18 strutting grounds combined) in 1978 (39) was twice as great as that in 1979 (19) (Fig.3), no detectable decline in total March and April counts of females actually occurred (X =1.29, P<0.2). There were many more lek visitations by females during May in 1978 than in 1979, which we attribute to renesting attempts by females whose clutches were lost during the inclement weather in early May 1978. Female visitation to leks had ceased by 1 May in 1979.

During both the pre-disturbance period and the post-disturbance period, the artificial strutting ground was not utilized by the sage grouse population. On 15 April at 1830 hours 2 hens were flushed 50 m north of the alternate site. Subsequent observations on or near this area included one female on 25 April 35 m SW of the site, and one female on 27 April 50 m NW of the site. These latter two observations were believed to be of a hen which nested 80 m N of the alternate site, initiating her clutch on 1 May.

An interesting series of events began on 7 April. Two tagged female and one untagged male sage grouse were flushed in the NE1/4 SW1/4 of Sec. 7. On 10 April (0545 hrs) 9 males were observed strutting, scattered throughout an adjacent area of similar habitat in the NW1/4 SW1/4 of Sec. 8. One of these males had been captured on 1 April on the Sec. 17 strutting ground and was accompanied by four female Later, on 10 April (1820 hrs) 4 male and 6 female grouse were observed at the same location. On the following day (0700 hrs) 20 bird (5 males and 10 females and 5 unidentified) were observed in the same vicinity. Thereafte no sage grouse were observed at this site.

The observations of 7 through 10 April help to clarify the sequence of responses of the sage grouse lek attendance to destruction of their traditional strutting ground whi occurred immediately following the initial disturbance of the Sec. 17 strutting ground.

This occurrence of a relatively large group of birds on an area equidistant to the Sec. 17 and Sec. 18 strutting grounds and the Sec. 8 artificial lek site coincided with a low point in male and female observations on the two strutting grounds (Figs. 4 and 5). However, more importantly, it marked a point at which at least a portion of the local population had been deterred from using the traditional strutting ground and was in the process of selecting an alternate site to continue it reproductive activities.

In summary, strutting activities were successfully moved to a proximate satellite strutting ground when the traditional major lek site was disturbed. However, our efforts to move the birds to an artificial lek site wher sage grouse are not known to have strutted previously were unproductive in 1979.

DISCUSSION

This new technology of Sage Grouse mitigation may some day develop into a cookbook methodology. A set of information on the impacted grouse population needs to be develope prior to disturbance. An alternate site need to be chosen using a set of guidelines describ ing an ideal strutting ground. Close coordin tion with the mine plan for the development i required.

When the 1980 breeding season begins, th Sec. 18 satellite lek will have been removed during construction of the railroad spur line The 1979 efforts at the alternate lek site will be repeated and improved. We plan to expand the sagebrush cleared area and increas the number and style of decoys. The fence line near the alternate lek site will be move

Nonetheless, it is possible that in 1980 the grouse will move still further west to th Hoadley Road lek rather than adopt the alternate lek site. At this juncture, it appears easier to move a group of displaying birds by destruction of the traditional display ground to a location where a few birds have displayed occasionally (satellite lek) than to a totally new location no matter how well chosen.

It is probable that despite the most complete destruction of a known strutting ground that the females will be inseminated and eggs will be laid. Thus, a strutting ground can be destroyed without destroying the reproductive potential. The quality and quantity of nesting, brood rearing and wintering habitat remain as the controlling factors in the success of the species in an area.

The current emphasis on the lek as the focus of protective measures may be less justifiable than evaluation and reclamation of suitable sage grouse habitat. Any buffer zone around the display ground is only an intermediate measure until our knowledge of habitat selection by the grouse is improved. At that point the emphasis needs to be shifted from reclamation following mining to a standard suitabale for replacement of the habitat for a population at the same level as previous to mining or better.

Rothenmaier, D. 1979. Sage Grouse Reproductive Ecology: Breeding season movements, Strutting ground attendance and site characteristics, and nesting period. M.S. Thesis, University of Wyoming, Laramie, 97 p.

Minimizing the Effect of Surface Coal Mining on a Sage Grouse Population by a Directed Shift of Breeding Activities [1]

Robert L. Eng[2], Edward J. Pitcher[3], Sam J. Scott[4], and Robert J. Greene[5]

Abstract.--Sage grouse which displayed on an arena scheduled for surface coal mining were studied from 1974 to 1978 to determine nesting, brood rearing and wintering areas used. Based on these data, a new lek was created in 1978 two miles away, equipped with decoys and a system to produce sounds of an active lek. A minimum of 7 cocks and 8 hens attended in 1978. The experiment was repeated in 1979 and 16 cocks and 18 hens attended.

INTRODUCTION

The removal of sagebrush (*Artemisia sp.*) and the resulting deterioration of sage grouse (*Centrocercus urophasianus*) habitat has been in effect at least since homesteaders first initiated dryland agriculture in many areas of the west. In addition to the plow, intensive grazing management and its associated sagebrush removal practices have made inroads into this habitat type. More recently, although on relatively smaller acreages, surface coal mining has resulted in some removal. Although most sagebrush removal in areas inhabited by sage grouse will have some degrading effect on the population, the degree of this effect will hinge largely on the extent and location.

Wintering areas hold some of the highest densities of sage grouse and may be used on an annual basis by birds from several strutting grounds or leks. Such areas may be key habitat segments for seven to eight months of the year and have considerable influence on grouse distribution over a wide area (Eng and Schladweiler 1972). Wallestad (1975) further stressed the importance of such areas by linking them with spring habitat and calling them wintering-nesting complexes. The strutting ground is also a critical segment since both males and females show a high affinity to return each year and most females nest within a two-mile radius (Wallestad and Pyrah, 1974; Wallestad, 1975). Thus, a sage grouse population may be more sensitive to the loss of either of these habitat segments than those used during summer or early fall.

Since a proposed expansion of coal mining in southeastern Montana encompassed an active sage grouse lek, Decker Coal Co. initiated and funded a study to provide baseline data for possible use in implementing mitigation measures. The study has been conducted seasonally since 1975 in cooperation with the Montana Fish and Game Department and Montana State University. The authors acknowledge the assistance of Steve Knapp of the Montana Fish and Game Department and Brent Stettler, Marvin Hoyt and John Berry of Peter Kiewit Sons' Co.

METHODS

An area of study around the lek to be disturbed (Penson lek) was selected on the basis of topography, known cover-types and published annual sage grouse movements data. Winter distribution was determined largely by systematic aerial coverage of this area (approximately three townships) at which time sightings of both birds and tracks were recorded. Aerial and ground coverage were utilized to locate other leks.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, Colorado, July 16-20, 1979. Published as Journal Series No. 966, Montana Agricultural Experiment Station, Bozeman, MT.

[2] Professor Wildlife Management, Montana State University, Bozeman, MT, 59717.

[3] Wildlife Coordinator, Peter Kiewit Sons' Co., Sheridan, WY, 82801.

[4] Environmental Supervisor, Peter Kiewit Sons' Co., Sheridan, WY, 82801.

[5] Fish and Wildlife Biologist, Mont. Fish and Game Dept., Warm Springs, MT, 59756.

Annual seasonal peak numbers of grouse in attendance on the Penson lek (S_P) were first obtained in 1974. Similar counts were obtained from two other leks, S_1 and S_2 which were first located in 1976 within the study area and S_3 located in 1977 just south of the area.

Cannon-net trapping was conducted on the strutting grounds in the following schedule: the Penson in 1976 and 77, S_1 and S_2 in 1976, 77 and 78 and S_3 in 1977 and 78. Six females from the Penson were equipped with radios in 1976, six in 77, and 6 each on S_1 and S_2 in 1978. All other females captured were marked with poncho markers (Pyrah 1970) and males with patagial markers.

Two road routes were established, one near the mining area (covered twice monthly) and another in the vicinity of leks S_1 and S_2 (covered monthly). These routes were used to provide production data, relocations of tagged grouse and general grouse distribution.

Based on data gathered during 1976 and 1977 as presented in the results, a potential site was selected for a "new" strutting ground two air miles SSE of the Penson ground. An attempt to clear the sagebrush by burning in September, 1977 was unsuccessful due to lack of ground fuel. Sagebrush and snow was removed with a blade in late February, 1978 from an area approximately 12 acres in size.

Twenty-five silhouette decoys were placed on the experimental lek (S_A) in early March, 1978, arranged to simulate a mating center (Wiley 1978). A battery-powered tape player with two speakers was camouflaged at the edge of the lek. An endless tape with sounds recorded from an active sage grouse lek was used. The sound equipment was activated daily, one hour before sunrise for a four-hour period by a 24-hour timer.

RESULTS

Four sage grouse leks were known to be active on or near the study area in 1977, the Penson (S_P), in the mining area, S_1, S_2 and S_3 (fig. 1). Also included in figure 1 is the location of the experimental lek, S_A. Winter distribution data of the grouse from 1977-79 showed a close relationship between winter-use areas and lek locations although winter snow

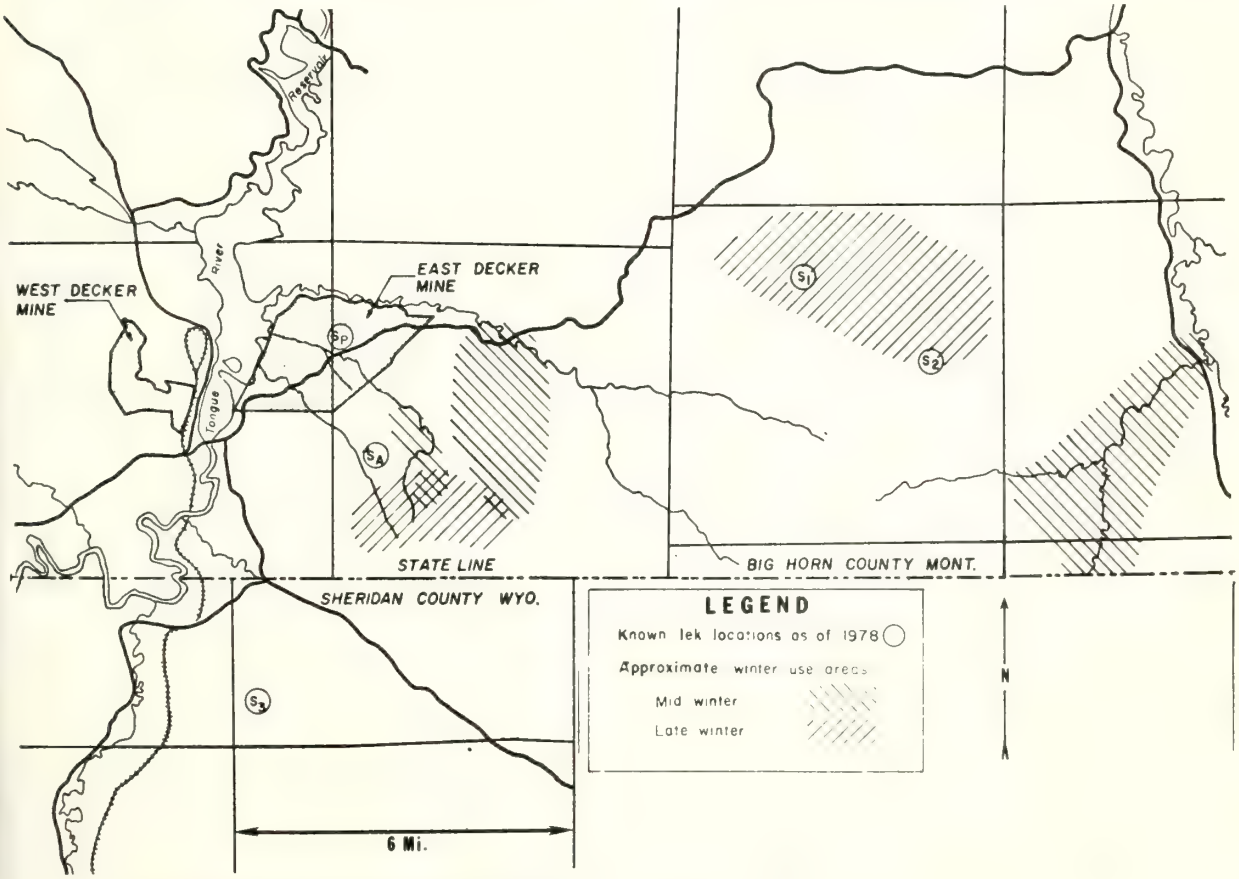

Figure 1. Lek locations and winter distribution of sage grouse.

conditions precluded close observations from the ground and consequent tagged-bird identification.

Peak counts of displaying males on the Penson lek have declined steadily from 1974 when 23 males were noted, through 1979 when six were observed. Data from S_1, S_2 and S_3 are not complete for a comparable length of time. However numbers of males attending these leks have remained relatively stable since 1977. Thus, the comparisons that are available suggest the decreasing level of attendance on the Penson may be due to an increased local disturbance factor. Even though Decker Coal Co. closed a mine entrance road which was near the lek, the overall increase in traffic and noise level in the area may have contributed to the decline.

The dispersal pattern of nesting hens which were radio-tagged on the Penson lek in 1976 and 1977, plus one nest site located in 1975 and one in 1978 are illustrated in Figure 2. The majority of nesting activity was to the east and southeast of the lek. An extension of this direction is indicated by the brood-use areas and by some of the radio-tagged hens into the summer (fig. 2). Thus, the grouse from the Penson lek showed a tendency to use certain areas during the nesting, brood rearing and wintering periods similar to Wallestads (1975) reference to a wintering-nesting complex.

Although most data confirm the extremely high fidelity which male sage grouse have for a lek (Wallestad and Schladweiler 1974), Wallestad (1975) reported a 25-30 percent yearly interchange between leks by hens. Although daily observations of all the leks in this study were inadequate during the peak of breeding to establish a percent interchange, figure 3 illustrates the observed between-lek movements by marked female grouse. Interchange of hens between leks is probably a result of birds from several leks using a common wintering area. Since hens of all ages and yearling males are frequently in common flocks during the winter, the interchange between grounds by adult hens play an important role in recruitment of young birds to a "new" lek. Thus the potential recruitment base for the experimental lek (S_A) would probably include birds from the Penson (S_P), S_1 and S_3 leks. In support of this supposition, one marked female from S_3 was

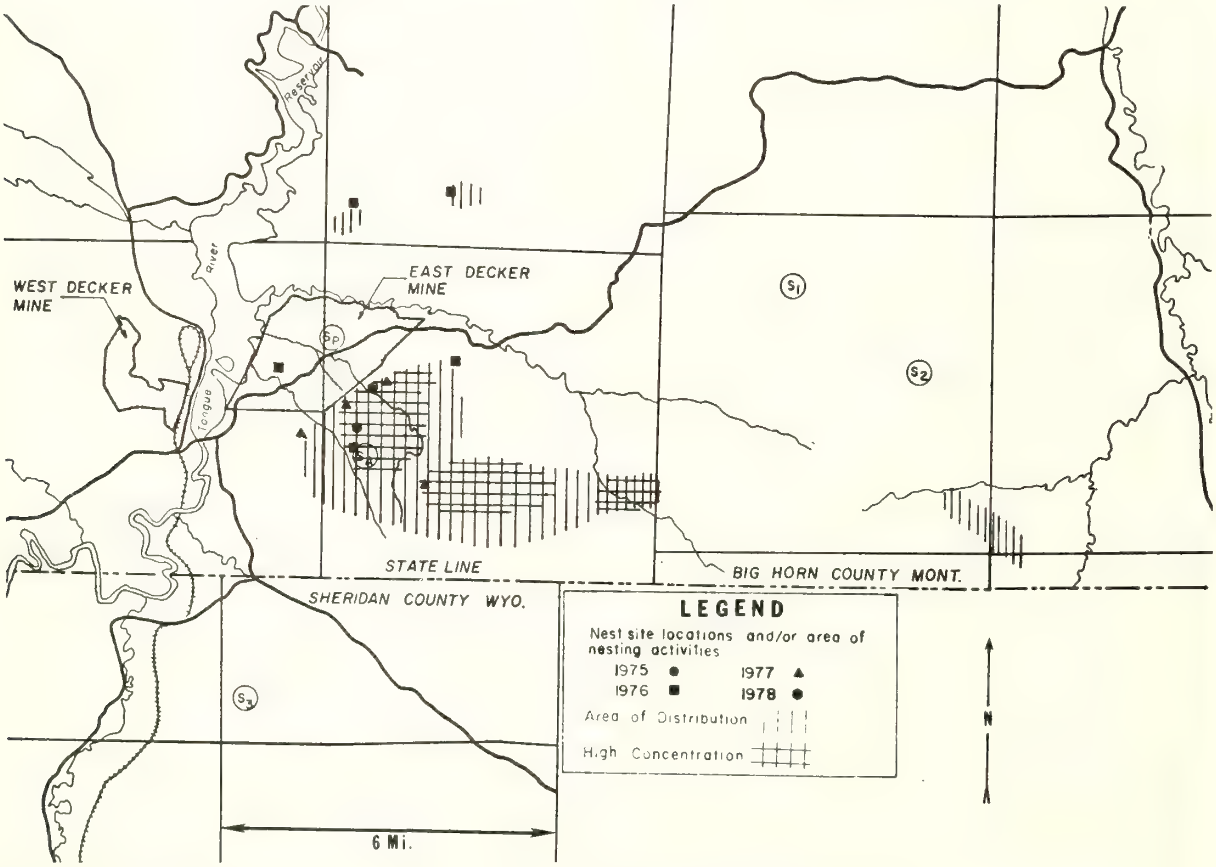

Figure 2. Dispersal pattern of nesting and brood rearing activities of female grouse from the Penson (S_P) lek.

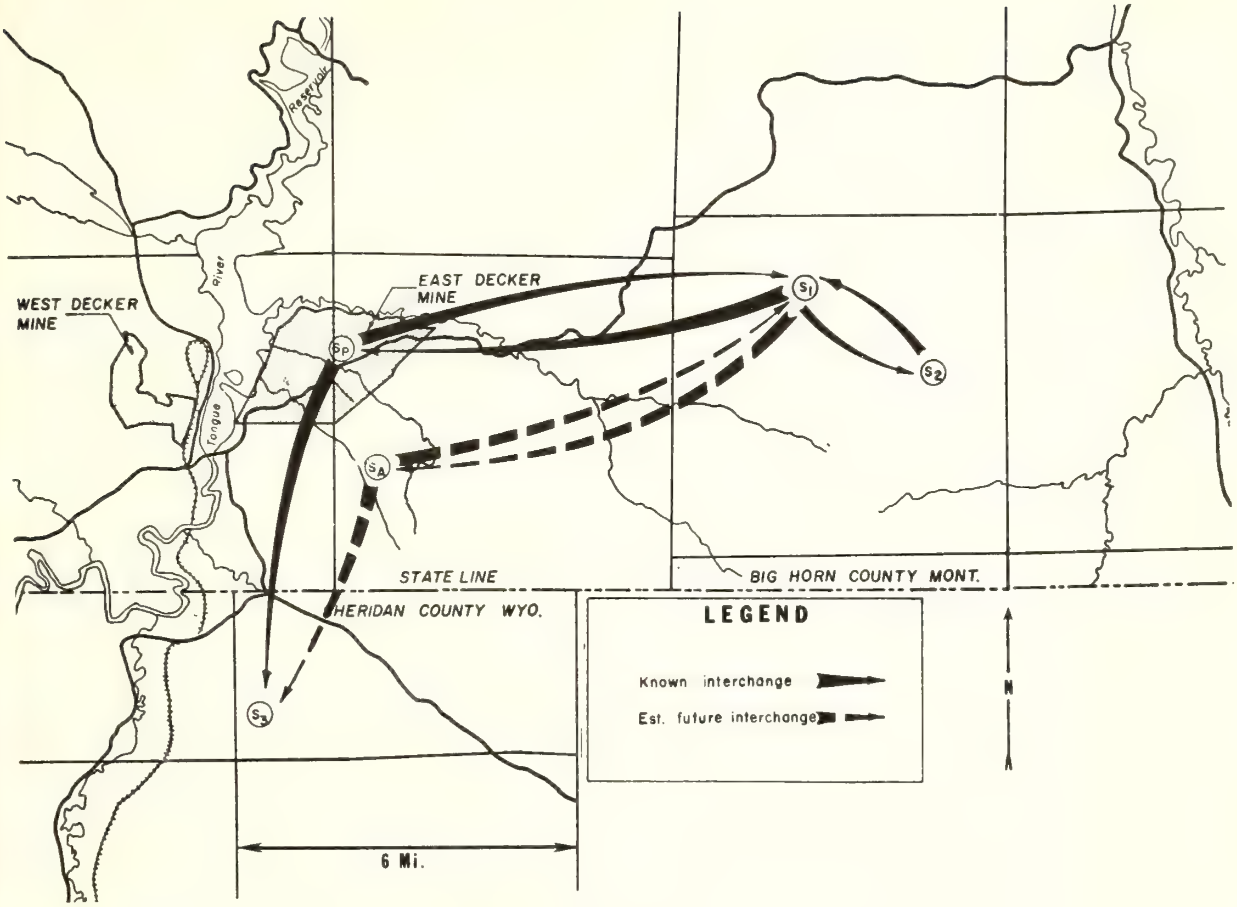

Figure 3. Known and estimated interchange between leks by female grouse.

observed at the "new" lek during the peak of strutting activities in 1979.

A few days after the sound equipment and decoys were placed on the experimental lek in 1978, a single yearling male arrived and initiated strutting activities. This was followed by the irregular attendance of one or two additional yearlings until by the second week of April when five to seven yearling males became regular attendants. Although none of the yearling males were marked, the arrival of six on the experimental lek coincided with the loss of six yearlings from the Penson lek. No yearlings were observed on the Penson for the remainder of the season.

Females began arriving on the experimental lek in early April and by the second week a high count of seven hens was reached. The peak of hen attendance was about one week later than observed on S_1 and S_2 suggesting that most of the hens recruited to the experimental lek were sub-adults.

Decoys and the sound system were again placed in position and operation on the experimental lek in early March 1979. A single adult male was the first to appear followed by irratic appearances of three to four sub-adult males. After four days, the decoys were removed. Near the end of March, the sound system was discontinued. A peak of 18 females occurred in the presence of eight males in the second week of April. On six mornings, copulations were observed. After the females began dispersing for nesting activities, continued recruitment of yearling males brought the peak seasonal male count to 16. During this same period of time, the Penson lek reached a peak attendance of five-six adult males and two females.

DISCUSSION

The sage grouse lek is a very traditional segment of this birds habitat. Wiley (1978) reported observing strutting activities on a lek studied 28 years previously by John Scott of the U. of Wyoming. Such tradition precludes the frequent establishment of new leks. A 169 square-mile area in central Montana which harbors 10 sage grouse leks has been surveyed annually for 25 years. During this period only two new leks are known to have been started, both of which appeared to be a shift from an existing lek to a location about 1 mile away.[6,7]

The experimental lek initiated in this study appears to be established. Breeding was observed during the 1979 season and with a minimum of 16 males and 18 females having attended the lek, tradition will very likely dictate perpetuation of this lek. Also, the radius of influence from nesting hens should assure continued use of previously used nesting habitat, losing only that which is temporarily lost to the mining activity. Therefore the continuation of the population segment, previously represented by the Penson lek, is assured.

Whether or not a new lek would have been established without artificial assistance is open to question. The existing data suggest not. The declining numbers on the Penson lek since 1974 suggest that increasing disturbance and continued high noise levels would have discouraged annual recruitment needed for the maintenance of numbers, and a gradual reduction to abandonment would have occurred.

In initiating the new lek, sound seems to have played the lead role in recruiting birds. Although initially, some strutting activity was observed in and around some of the decoys, ultimate clustering of birds took place away from the decoys. Sound produced by the speakers was adjusted to a greater volume than normally produced on an active lek and consequently probably had a greater effective radius than natural leks in recruiting unattached birds.

The location selected for the experimental lek was based on two years data on nesting, brood rearing and wintering areas of birds from the Penson lek. Although many of these activities were carried on in common areas, the relationship of the site to wintering areas was probably most critical. This permitted an intercept of females and yearling males, which normally arrive at a lek later in the season than adult males.

Much of the information utilized in this mitigation effort was based on previously published biological data supplemented by on-site field studies. Certainly other comparable situations are present where existing data, when applied, can greatly assist in solving mitigation problems. Members of the wildlife profession have an opportunity and an obligation to assist in solving such problems.

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[6] Eng, unpub. field notes.

[7] Pyrah, Pers. comm.

A Review of Factors Involved in Bird-Tower Kills, and Mitigative Procedures[1]

Bernard N. Jaroslow[2]

Between 5 million and 80 million birds are killed annually from collisions with man-made structures, with the largest kills occurring to passerine species on overcast nights during fall migration. An understanding of avian physiological and behavioral factors conducive to collision helps in development of methods for mitigation. Mitigating factors involve structure siting, light-source type and frequency of the signal, and precautionary measures for overcast weather and bird migration seasons.

INTRODUCTION - THE PROBLEM

Records of bird kills from collisions with man-made structures were made before the turn of the century. Lighthouse keepers early recognized the positive correlation between foul weather and the number of birds killed. They also recognized that the beacon light served as an attractant for birds in overcast weather, and attempted to mitigate the attraction by using colored filters and varying the flashing rates (Avery et al., 1978).

According to Banks (1979), an estimated 1.25 million birds are killed each year from collisions with towers, tall buildings, monuments and lighthouses, and 3.5 million die from collision with windows (Banks, 1976). According to the newsletter "Ecology USA" (May 7, 1979), this total is closer to 80 million birds.

One of the more thorough investigations of the problem of bird collisions is an 11-year study conducted at a TV tower in Leon County, Florida (Stoddard and Norris, 1967).[3] The largest single-night kill was estimated as between 4000 and 7000 birds in October 1955, with a 2500-bird kill recorded in October 1957. Over the 11-year period, about 30,000 carcasses were examined, although the number actually killed is probably several-fold higher because many birds were not found in the weeds or had been taken by scavengers.

The nightly toll during migration is highly variable. In 12 nights of bird collection at a TV tower in Topeka, Kansas, in the fall of 1954, the nightly kills ranged from 3 to 585, with a median of 25 (Tordoff and Mengel, 1956).[3] Finches and warblers composed about 70% of the victims; ovenbirds, vireos and thrushes made up another 25%. These proportions vary from one report to another, but the groups listed are consistently the major victims of bird-kills by collision. Hassler et al. (1963), using radar, found that some birds elected to fly under the overcast and others flew above. This is likely to be species- or group-specific behavior which might account for the preponderance of passerine birds that are victims of collision with towers and skyscrapers.

The most spectacular bird-kills have been the kill estimated at 15,000 to 30,000 birds at a 1000-foot TV tower, on the night of September 18, 1953, near Eau Claire, Wisconsin (Kemper, 1964), and the kill estimated at 50,000 birds at a ceilometer on the Warner Robins Air Force Base near Macon, Georgia, on the night of October 7-8, 1954 (Johnston and Haines, 1957).

Given this problem, the objectives of this paper will be to examine: 1) the conditions that lead to bird kills via collisions;

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[3] These studies are typical of the findings reported by many others. Avery et al. (1978) have published an excellent annotated bibliography which is concerned with the types and numbers of birds killed at principal sources of impact, e.g., TV towers, lighthouses, monuments, and around ceilometers.

2) the physiological and behavioral factors conducive to such collisions; and 3) some successful and proposed mitigative procedures.

CONDITIONS THAT LEAD TO BIRD-KILLS WITH STRUCTURES

Three major factors that lead to bird collisions with stationary objects are:

- "Invisibility" of the Object--A raptor in pursuit of prey, and waterbirds taking off in panic, may collide with transmission lines; low-flying nocturnal migrants often collide with tall, unilluminated structures such as buildings, stacks, and towers.
- Deception--The bird sees a continuation of air space beyond a reflecting window and strikes it at full flying speed.
- Confusion--Discrete sources of light attract, confuse, and disorient night migrators on overcast nights (for example TV towers or lighthouses).

Analysis

Invisibility

When birds strike wires, it is probably because the object has become "invisible" owing to inattentiveness of the bird. A falcon pursuing a pigeon or a flock of ducks taking off in panic may be too intent upon what it is doing, and, consequently, does not see wires. In transmission line corridors carrying more than one powerline, e.g., a 345-kV and a 765-kV system in the same corridor, the wires provide a formidable obstacle course for a panic-stricken flock of birds.

Transparent walls (windows) or glass-walled corridors which provide a view of an open outdoor space have been a source of constant, low-level kills of resident and migrating birds (Banks, 1976).

Birds flying at night may not see a structure in their flight path. The occasional large bird-kills that take place on clear nights during migration (Taylor and Anderson, 1973) may, conceivably, occur when an atmospheric temperature inversion with a low-level jet stream (<2000 ft. altitude) develops (Taylor, 1954). The migrating birds may descend to take advantage of the tail wind and large numbers collide with obstacles projecting into their air space (Hassler et al., 1963).

Deception

Birds that fly into windows are deceived by the reflections. A straight-on view reflects the clear flight path that the bird is using; from an angle, some other clear path may appear. This type of problem could occur either by day or by night.

Confusion

The most dramatic bird kills recorded are probably those that result from confusion. They occur when the sky is overcast (with and without rain, drizzle, or fog) and when light sources are present to attract the migrating birds. The light appears to serve as an attractive super stimulus in the absence of light from celestial objects.

Cochran and Graber (1958) graphically described how the area around a TV tower was occupied by a heavy concentration of birds circling around, and fluttering about in confusion. They suggested that the illuminated area around the TV tower served as a lighted room which many birds were reluctant to leave. Birds repeatedly circled the tower until they collided with guy wires or the tower frame, or finally fell exhausted to the ground. The behavior of the birds, and the numbers killed, were unaffected by whether the tower was or was not transmitting.

BEHAVIORAL FACTORS

There are several questions that must be answered before we can understand why the birds are killed in such large numbers and before we can develop methods for mitigating the magnitude of the problem. First, why are the birds attracted to the lights on overcast nights? Second, why do they fly around the lights until they are exhausted? Third, why do they seem to be so disoriented that they fly into the ground or into large, illuminated structures such as monuments and cooling towers?

To answer the first question we might examine the method by which birds navigate at night. The explanation for the large tower kills on overcast nights probably does not reside with a single behavioral response associated with migration; instead, it is the result of the relative strengths of different behavioral patterns at different stages of the migration.

It is now generally accepted that long-distance migrants primarily use celestial navigation (Emlen, 1975). The first phase of setting out on a migratory flight is to determine the direction of the goal. According to the experimental data of Wiltschko and Wiltschko (1976, 1978), the initial orientation is determined from the geomagnetic field. The birds then take a bearing on the stars and use celestial navigation during the actual flight. The ability to navigate by the sun and stars during migratory flight includes the ability to compensate for the movement of the stars during the night (Emlen, 1975; Sauer, 1958).

I propose that, under overcast skies, the dominant orienting stimulus of celestial objects is lost; then, the dominant stimulus becomes the geomagnetic field. Leask (1977) suggests that the signal is associated with the optic apparatus and that the weak radiation of the geomagnetic field is amplified by a mechanism in the eye which is capable of "optical pumping." Whatever the mechanism is for sensing the geomagnetic field, the strength of this stimulus appears to be weak. The geomagnetic orientation may be maintained and strengthened by "consensus" of the flock, i.e., Graber (1968) reports "... migrants flying under complete overcast were extremely vociferous. As the cloud layer broke, calling declined, but as the overcast closed again about 2200 CST, calling began to increase again ...."

In any case, the strength of the orienting stimuli, in some night-migrating birds, is less than the stimulus produced by a point source of light when the sky is overcast. Kemper (1964) suggests that birds flying under overcast conditions orient on tower lights as they would on stars. As they approach the light their direction of flight relative to the tower light changes, and they are no longer in conformance with the celestial orientation established at or before take off. To make navigation corrections on what has become their "guiding star," the birds begin a spiral around the light. This terminates in collision with the tower or its guy wires, or with exhaustion and collapse on the ground.

Sometimes the point source of light is a ceilometer or an illuminated structure. When the birds enter the illuminated area, they appear to be confused and circle inside and around the illuminated area until they fly into a nearby structure or fall exhausted to the ground (Howell et al., 1954; Johnston and Haines, 1957) while in the beam of a ceilometer; and there is a report of many birds, on a rainy night, flying into the ground around a recreation area that was illuminated with tall light poles (James, 1956).

Herbert (1969) gives a convincing argument in explanation of the confusion and disorientation of birds when they fly into an illuminated area, particularly in rainy or misty conditions. He suggests that, in night flights, the birds stabilize themselves on a horizontal horizon, with lighter areas above and darker masses below the horizon. In the illuminated areas of a light source, they become disoriented and may suffer vertigo when their sense of gravity is at variance with their sense of vision. As a result, birds in the light beam are seen to flutter in a confused manner. Some of the birds are apparently so visually confused that in these situations they appear to accept the edge of light and darkness as the horizontal horizon, and fly into the ground; other birds refuse to leave the cone of light, flying round and round until they fall to the ground exhausted (Cochran and Graber, 1958; Howell et al., 1954; James, 1956; Johnston and Haines, 1957). In his discussion, Herbert points out that pilots have shown the same disorientation when confronted by bright lights on dark nights.

MITIGATION

Collisions resulting from "invisibility" of an object involve wires (e.g., transmission lines, telephone wires), transparent walls (glass-walled corridors between buildings), and tall structures not visible on dark nights.

Mitigation of kills by overhead wires and cables could be accomplished by conscientiously avoiding, where possible, the stringing of wires across flight corridors, for example, near lakes and ponds used by water birds, or across major migration corridors such as the Mississippi flyways (Goddard and Richardson, 1974). Silhouettes of raptors on windows have been used with success to reduce bird losses from collision with windows or window walls (National Wildlife, 1976). Tall, dark structures could be illuminated on clear nights but left darkened on overcast nights, when they would serve as an attraction and hazard.

Collisions resulting from deception occur when birds see a reflection of open air space and fly into the reflective surface, a frequent problem with modern architecture, which uses large areas of glass. In many instances, reflectivity is enhanced because the windows are covered with heat reflectors which can serve effectively as mirrors. This hazard primarily affects diurnal residents and migrants.

Mitigative procedures are several, but the easiest way to decrease the fidelity of the reflected image is to have white-lined drapes in the room, or have the room lights on in the daytime whenever bird-strikes are likely to become frequent. Any method that would decrease the fidelity or the brightness of the reflected image would be helpful.

Collisions resulting from disorientation, with subsequent confusion, are associated with night migration on overcast nights. The disorientation results from stationary lights on the ground or on towers.

The study by Cochran and Graber (1958) provides information useful in understanding the causes of disorientation and in developing mitigative procedures to decrease collisions. By counting the number of bird calls per minute, they found that the numbers were much higher when the lights were on and decreased rapidly as soon as the lights were extinguished. They used different on/off sequences for tower lights and found that the number of bird calls increased about two minutes after lights were switched on, and by four minutes after illumination the frequency was at or close to maximum. Immediately after the lights were extinguished, the birds left the vicinity of the tower, as evidenced by the diminishing volume, as well as number, of bird calls. In support of the mitigative efficacy of intermittent illumination on the size of bird kills is a reference to an experiment at Dungeness Lighthouse in which the newly installed lighthouse beacon was flashed for one second in every ten-second period (Avery et al., 1976, citing Baldwin, Ontario Naturalist 3:3-11, 1965), and the numbers of birds killed declined from previous years when the illumination had been constant.

Mitigative procedures for aircraft warning lights on towers and tall structures should provide for a lighting sequence in which the lights are on for no more than two minutes and off for less than one minute on overcast nights during the migration season. Further research might show that a ten-second cycle, such as used at the Dungeness Lighthouse, is both feasible and effective. The light intensity should be decreased as much as is compatible with its function as a warning light. This would limit the zone of attraction and the intensity of the stimulus.

Illumination of tall structures such as monuments and cooling towers (Rybak et al., 1973), when used for esthetic purposes, should be stopped during the danger period. The lights in skyscrapers should be extinguished, if possible, or drapes should be drawn at those times.

Many experiments have been conducted to determine cause-effect relationships between different colored lights and bird collisions with illuminated structures, but the results are inconclusive.[4] This is not surprising. Studies of color vision in birds (review by Stillman, 1973) show that color sensitivity is highly variable among different families. Most unfortunately, few of these studies were concerned with passerines, due, in part, to the difficult technical problems in working with these small birds. A thorough study (Donner, 1953) of spectral sensitivity in pigeons showed that they have good vision over the entire region that humans call "visible light."

Ceilometers, because of their intense beam, provide a super stimulus, and attract migrators from many miles. Fortunately, mitigation of the problem is simple - use of ultraviolet light (Terres, 1956; Tordoff and Mengel, 1956) or infrared light (Donner, 1953). Both are invisible to birds but easily detected with instruments. According to Mr. Donald Whitman, Chief of Data Acquisition, National Weather Service, Central Division (Personal Communication), all U.S. airports use rotating beam ceilometers with continuous recording. Rotating beam ceilometers give light in the infrared range. (For example, the light source advertised by Weathertronics, Inc., is described as a laser diode that emits 400 W, peak power, at 900 nm.) A fixed-beam ceiling light is sometimes used with a five-minute on-off cycle. I am unaware of any bird-kills associated with the use of either system.

SUMMARY

Between 5 million (Banks, 1979) and 80 million (Ecology USA, 1979) birds are killed annually by collision with man-made structures. They collide with objects that are poorly visible, such as wires strung across their flight path; objects that deceive by reflecting a free flight path; or, on overcast nights, structures with point sources of illumination which act as super stimuli that attract, disorient, and confuse.

Mitigation can be achieved by better siting of wires, decreasing the reflectivity of surfaces, substituting ultraviolet or infared light in ceilometers, and using an appropriate on-off cycle for warning lights and ceilometers on overcast nights during migration (further research is required to determine the optimum cycle). Illumination for

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[4] See the annotated bibliography of Avery et al. (1978) for references to these studies.

esthetic or advertising purposes should be extinguished, whenever possible, during danger periods.

ACKNOWLEDGMENTS

I wish to thank Ms. P. Merry, Dr. L. Soholt, and Dr. E. Pentecost of Argonne National Laboratory for their helpful contributions and discussions during the preparation of this manuscript. I am grateful to the Nuclear Regulatory Commission and the Department of Energy for support.

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Evaluation of the Potential Impact of Proposed Recreation Development on the Mineral King Deer Herd[1]

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Abstract.--A study in 1976-7 of the Mineral King deer herd in California assessed herd ecology and impacts of proposed recreation development, and formulated mitigation plans. Field studies defined range condition and utilization, herd size and composition, migratory movements, and disturbance by existing recreation. Range improvements, better herd management, and modified development were principal mitigations recommended.

INTRODUCTION

Mineral King is a 16,000 acre subalpine valley in the central Sierra Nevada Mountains in California. The glaciated valley floor, at an elevation of about 7,600 feet, is predominately meadowland interspersed with brush and conifer stands. The adjacent slopes, which rise sharply to surrounding peaks as high as 11,000 feet, are covered with dense montane brushfields or coniferous forest below timberline and channelled by several streams which drain lakes in high elevation cirques. Many of these barren, steep cirques face north or northeast, so that a deep snow pack often lingers late into the spring.

During California's Gold Rush era, Mineral King received its present name and experienced a "silver rush." From 1870 to 1890, mining activities boomed, and as many as 3,000 people inhabited the area. Although later the silver proved difficult to separate from the ore, it was because of the purported mineral values that it was excluded from the Sequoia and Kings Canyon National Park, created in 1890, which surrounds it on three sides. Instead it was assigned to the United States Forest Service (USFS), Sequoia National Forest. In 1926, Mineral King became a national game refuge, and no hunting was allowed for 25 years.

As early as 1945, the Forest Service recognized that Mineral King had the physical attributes and geographical proximity to the large population centers of Southern California that could make it a year-round recreation center, with special potential for winter sports. At that time and again in 1965, the USFS invited development proposals from private industry. Walt Disney Productions, Inc. was awarded a three year preliminary planning permit in 1966 and conducted extensive research on the skiing potential of the area.

The passage of the National Environmental Policy Act (NEPA) in 1969 mandated environmental impact assessments for any federal developments, and prompted the preparation of the Mineral King Final Environmental Statement (FES) in 1976. The preferred alternative development plan was designed to accomodate 6,000 persons at one time (PAOT) in the summer months and 8,000 PAOT during the winter season. Proposed facilities included a 25 acre village with hotel space for 2,500 people located in the heart of the valley, numerous ski lifts to the upper bowls and north-facing cirques, 30 acres of parking and day facilities at Faculty Flat in the western end of the valley, and overnight accomodations and service facilities for about 2,500 visitors located 5 miles from the valley at the existing settlement of Silver City.

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The USFS realized that a thorough study of the deer herd should be undertaken to define herd ecology, identify adverse developmental impacts on herd productivity, and formulate mitigation measures to ameliorate losses. Accordingly, this study was initiated October 1, 1976, and herd observations and range analyses were conducted through November, 1977. The final report containing impact assessments and mitigation recommendations was completed in June, 1978 (Cornett et al., 1978). Recently, the Mineral King Game Refuge has been transferred to the Sequoia and Kings Canyon National Park by legislation, reducing the possibility of intensive development. However, if any sort of development is considered by the National Park Service (NPS) in the future the management procedures we suggest still apply. The deer herd could still be utilized by hunting on the winter range outside the park.

METHODS

During the initial months of the study, herd composition and seasonal movements were observed, and the yearlong ranges delineated from existing knowledge and verified by field reconnaissance. A comprehensive literature review was undertaken to obtain historical information, define herd biology and food habits, and identify potential management alternatives for mitigation.

In 1977, key winter and summer range areas were intensively surveyed to determine vegetative composition, range condition, and deer utilization of distinct habitat types as measured by the pellet count technique (Neff, 1968). Migratory and adjacent summer ranges were also surveyed by extensive reconnaissance.

During the summer of 1977, three full time field researchers evaluated population distribution, range utilization, and the effects of existing human disturbance in Mineral King on the deer herd during fawning. At this time Mineral King and its environs were used for summer recreation such as day hiking, backpacking, camping, horseback riding, and fishing. By evaluating the existing deer population densities in the various areas in the valley, particularly in development sites, the team identified the potential amount of habitat displacement that could be expected. Deer reactions to human activity along trails were observed, and deer habitat utilization near trails quantified by pellet counting. These studies allowed an estimate of the number of deer threatened by development.

RESULTS

Herd Ecology and Range Condition

The California mule deer (Odocoileus hemionus californicus) inhabiting the central western Sierras are migratory and are known to have distinct perennial territories on both winter and summer ranges with an established migratory route connecting the two (Bertram and Rempel, 1977). This herd usually completes the fall migration to winter ranges between 2-6,000 feet elevation by December, and the peak of breeding season occurs during this month. Over half the winter range area is dense, mature chaparral (chamise, birch-leaf mahogany, manzanita, etc.), and old live oak forests predominate on the rest. The dense canopy prohibits significant understory vegetation, and available forage is limited over most of the area. Annual grassland savannah with a low density of mature oaks is a heavily utilized cover type during winter, and though widely distributed in small patches is only a small proportion of the total acreage. The winter diet is mainly browse, oak mast, and grasses which are green and succulent at this time of year.

As the spring progresses herbaceous forbs begin to dominate the diet, and during the spring migration from April through June their rate of ascent seems highly correlated with the phenology of the herbaceous plants. The migratory ranges are mostly densely canopied with mature mixed coniferous forest, mainly ponderosa pine and white fir, also exhibiting limited understory plant production. Thus, riparian zones, meadows, and scattered small acreages of recently burned forest are key holding areas during migration due to relatively high forage production.

Arrival on the summer range in Mineral King is usually complete by late June, with fawning activity taking place mainly in July. The diet on the summer range is predominantly browse which is abundant in the refuge, but in riparian zones and meadows herbaceous forage, particularly forbs, is eagerly sought. The fawns grow rapidly, and by September follow the does closely where they travel. Migration from the summer range commences after the first fall precipitation with sub-freezing weather, usually in October. The fall migration may last 1 to 2 months, with browse and oak mast predominating in the fall diet. Weather conditions greatly influence the rates of both fall and spring migrations.

Population Trends

The Mineral King deer population was undoubtedly greatly reduced from pristine levels during the mining era. However, the creation of the wildlife refuge allowed recovery. Large burns on winter and migratory ranges in the mid-1930's favored the population, which peaked in the late 1940's. Longhurst et al. (1952) reported significant summer range damage in the valley at this time, and beginning in 1950 special hunts were held to reduce the population. Between 1950 and 1970, 10 hunts yielded nearly 2,000 deer, and averaged 36 bucks per year after 1968 when a regular buck season was established.

In 1969-70, Schneegas and Franklin (1972) studied population densities and the seasonal movements of marked deer. They found that the population had stabilized at levels much smaller than in the late 1940's, probably as a result of the maturation of winter and migratory ranges resulting from effective fire prevention. Our studies found the current population to be between 800 to 1,200 deer for the entire refuge, estimated by combining tag returns and pellet counts.

Disturbance Study

Assessing the effects of disturbance involved both deer observation and pellet counting. The main valley was divided into eleven sectors averaging about 200 acres encompassing the riparian valley bottom and the drier brush zone on adjacent slopes. Each sector was observable from a point on the opposite hillside, and was scrutinized during morning and evening feeding periods throughout the summer. Deer groups were identified by total number, age, and sex in each sector. In addition the date, time, location, cover types, and type of activity were noted. Selected sectors containing trails or roads were observed during high human use periods such as weekends and holidays, and on contrasting low use days during the week. The type of human disturbance and deer response as well as the approximate distance of separation were recorded.

The results of these observations indicated that deer became habituated to predictable human activity such as vehicles on roads or backpacking on established trails. In such cases deer were commonly observed either to ignore the activity or to watch alertly, often from only short distances, and retreat behavior was infrequent. However, random off-trail hiking commonly caused a retreat response. Off-trail hiking was especially high during hunting season, and at this time nearly all classes of deer were quite wary and harried.

Pellet counting was used at the season's end to quantify habitat utilization near disturbance. Pellet group densities were assumed to be directly related to habitat use. Two meadow areas were transected for comparative purposes, one located in the upper valley remote from concentrated human activity, and the other at the terminus of the main road near overnight parking, cabins, campgrounds, and a pack station. Although vegetatively and physiognomically similar, the area near the cabins received only about 40% of the total deer use measured in the control area.

Several transects were also placed perpendicular to hiking trails in three separate locations. The midpoint of each transect coincided with a hiking trail so that half of the plots were uphill and half downhill from the trails which followed hillside contours. The vegetation in all areas was similar, composed of mixed montane brush. The data for successive distance intervals from trails were combined and analyzed by a t-test. The results showed that within a 30-50 yard distance from trails, deer use was reduced to about 30% of adjacent habitat further away (Figure 1).

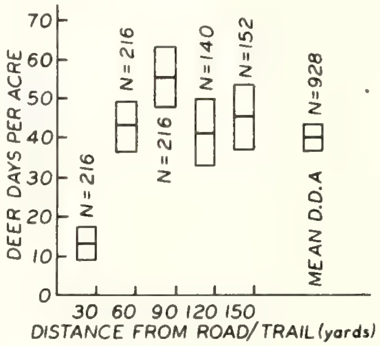

Figure 1. Deer days per acre and 90% confidence limits with plots grouped in 30 yard intervals perpendicular to road or trail.

Impact Assessment

Analysis of the impacts associated with the planned development utilized the results of the disturbance work just described. Locations, cover types, and acreages of planned facilities were determined according to the preferred alternative of the FES. Using deer density estimates in deer days per acre (DDA) obtained by pellet counting in the cover types involved, and the known length of the use period in days, the total number of deer displaced was calculated by the formula:

$$\frac{(\text{deer - days/acre}) \times (\text{\# acres affected})}{(\text{length of season in days})}.$$

The length of the summer season in Mineral King was about 120 days and the winter range use period 150 days in 1977; but the length of these seasonal periods will vary with annual weather patterns. On-site development impacts were expected to displace approximately 150 deer, or about 15% of the herd based on 1977 estimates.

DISCUSSION OF MITIGATION CONSIDERATIONS

Before mitigation can be effectively planned, implemented or achieved, involved parties must agree on what constitutes mitigation, what losses will occur, and the extent to which losses should be rectified (Rappoport, 1978). In some projects plans are modified so that potential wildlife losses will be prevented or minimized, but in most developments some losses are unavoidable. If a project is determined to produce a net loss of so many habitat units, acres, or animals, then a like number could be replaced off-site at another location. However, beyond acquisition of similar acreages in other areas with suitable flora and fauna, if the idea is to compensate or mitigate some proportion of the on-site losses habitat improvement becomes an extremely important feature.

The key to the most successful mitigation projects is preconstruction information that results in the inclusion of plans to offset and avoid losses during all stages of development. At Mineral King most displacement would have occurred on the summer range, perhaps interfering with fawning success. Fawn loss on summer ranges could be minimized, if human disturbance were managed or a reduced scale of development implemented. In addition, many deer, particularly fawns, are now lost on poor winter ranges. Deer overwinter survival could be increased to more than compensate for summer range displacements, if more forage were made available through winter range improvement. Therefore, recommended mitigation strategies for the Mineral King deer herd rely mostly on range improvement measures and management of human disturbance.

RECOMMENDED MITIGATION MEASURES

Land Acquisition - A 320 acre parcel of private land adjoining Bureau of Land Management (BLM) lands and various other privately owned acreages should be considered for acquisition. These lands would be useful not only for their locations on key winter and migratory ranges, but also for the control the holders exercise as lessees of adjacent BLM lands which form a large part of the winter range.

Winter Range Vegetation Manipulation - Winter range improvement could be achieved most satisfactorily by prescribed burning. The majority of the range is mature, decadent chamise and live oak chaparral which now receives little deer use because of its impenetrability and lack of available browse. However, both species resprout and reseed following fire to provide palatable, nutritious browse. The sprouts grow rapidly beyond reach within a few years if not browsed. Therefore burns must receive sufficient use the first season following manipulation to provide long term forage production. Biswell et al. (1952) stressed sprout suppression of chamise and interior live oak for brush control and reseeding to be successful.

Preferably, burns should be done on small 5-10 acre spots well distributed over an area to form as much edge as possible. Using this approach, the objective would be to burn about 70% of a chaparral stand, leaving approximately 30% mature brush for escape and thermal cover (Longhurst and Connolly, 1970). This would entail burning about 450 acres of brush per square mile of chaparral. However, on an annual basis, only about 10% or 45 acres per square mile should be burned each year to ensure a continuing supply of new brush seedlings and sprouts plus associated successional grasses and forbs.

Late winter or early spring burns are most desirable. Burns at that time of year, before chaparral growth commences in the spring, help to minimize erosion during the winter period with its high precipitation, and at the same time assure maximum brush regrowth by the time deer reach the winter range the following fall. Erosion on steep hillsides following burns of dense brush can be a problem where there is no herbaceous understory. The soil is looser than that under burned grass, and when deer feed over the slopes, soil moves downhill and is washed away during winter storms. Therefore, reseeding burned chamise areas may be desirable. Probably the best mixture for reseeding burns in this area, considering palatability for deer, would be a combination of Blando brome, Palestine orchardgrass, redstem and broadleaf filaree, and rose clover.

Migratory Range Improvement - Prescription burning is also the preferred tool for rejuvenating mountain mahogany stands and brushy holding areas on NPS lands.

Summer Range Improvement - Brush in ski runs should be trimmed to approximately three feet in height without use of herbicides. Some burning of particularly dense mixed brush and possible avalanche manipulation to maintain vegetation in successional stages should be considered.

Livestock Grazing - Often overlooked, controlled livestock grazing is another fairly cost effective tool for improving deer ranges. When used properly, seasonal livestock grazing does not compete with deer needs, but will aid in keeping vegetation in successional stages favorable to deer and reduce danger from wildfires. Also, when the grass is kept down more water will remain in the soil for browse sprouts which grow later in spring than the grasses. We suggest that sheep grazing in herded bands would provide more favorable results than cattle grazing. On the summer range, sheep can be herded into steeper and rougher terrain than cattle will normally use, and the season of use can also be controlled better than when cattle are turned out and left unattended. Possibly a mixture of sheep and cattle plus packstock in certain areas might yield the best results. Livestock grazing in fawning areas should be deferred until late July or early August after fawns are mobile.

On winter ranges, light livestock grazing should also be beneficial. However, we consider that the present level of cattle use of both private and certain portions of the BLM land in winter to be unacceptably high and it extends over too long a season. It would probably be best if livestock use could be confined to the late spring and early summer on the winter range to minimize competition with deer.

Population Controls and Hunting - A monitoring program is necessary to determine trends in numbers and productivity of the herd. This can be accomplished by annual herd composition and pellet counts on the winter range. If development in Mineral King should proceed, hunting should be restricted to the winter range. Either-sex quota hunting with flexible closing dates should be employed to hold deer numbers within range carrying capacity.

Road Closures - Access routes created to facilitate hunts and herd monitoring on winter ranges should be closed during the off-season to reduce poaching and harassment of deer.

Managing Human Disturbance - Results from this investigation's disturbance studies indicate that the greatest impact on the deer herd will be from the random movements of 6-8,000 PAOT in prime fawning territory.

Previous studies by the California Department of Fish and Game (CDFG) and USFS identify key areas on which fawns are dropped in May and June (Schneegas and Franklin, 1972). Actually, fawning occurs in suitable locations throughout the valley, especially around meadows and in brush fields, beginning in June and lasting through July. Because of the dispersed fawning locations, closure of all critical fawning areas to human use would be impractical. However, closure of certain campsites, especially in the upper valley, might be feasible.

We feel that most unnecessary disturbance could be minimized by planning and public education. A study of visitor impacts in Yosemite National Park (Foin et al., 1977) traced human use patterns around major centers and campgrounds, and then compared the vegetation and wildlife of such high use areas to little used but similar places. Trails through meadows received heavy use, but the rest of the meadows received low use, especially if wet. Dryer meadows encouraged more diffuse traffic. In general, placement of visitor objectives outside the meadows determined trail locations and use patterns. The forest adjacent to meadows received low use, but forests around campgrounds lost nearly all their understory vegetation.

It follows, then, that some disturbance can be eliminated by careful planning. Structures, trailheads and parking areas should be placed so that human traffic between objectives will create as few paths as possible and will naturally avoid areas suitable for fawning. Also, efforts to alert the public to the necessity of staying on trails and not harassing pregnant does and new fawns during June and July could prove effective. During August and September, human disturbance might move deer to other areas or change their daily patterns, but it would probably not have a significant effect on fawning success.

Reduced Development

The single most effective recommendation we can make concerning potential impacts on the Mineral King deer herd is to reduce the scale of development.

FES alternatives I, II and III all substantially reduce summer deer disturbance from the level which will occur with the preferred alternative, because none allows major centers to be built in the prime habitat of the valley itself. Alternative I is status quo (1,000 PAOT in summer), alternative II increases summer use to 1,400 PAOT and alternative III increases summer use to 4,000 PAOT and accomodates 5,000 PAOT during the winter ski season. Alternative III provides for seven ski runs to be constructed on north facing slopes outside the main valley with summer access to the valley provided by bus. With alternative III, approximately two thirds the people allowed for in the preferred alternative will be in the valley during summer. Camping activity would still be high but valley fawning territory would receive far less damage with no major construction of human centers.

Maintenance of Mitigations

Mitigation should not be a one-time effort. Range conditions and herd composition must be constantly monitored and managed to achieve and maintain desired goals. For initial plans and efforts to be successful, provisions to periodically check herd and range management progress should be included in the Mineral King herd management master plan.

Herd and range management should become a cooperative interagency effort between CDFG, USFS, BLM and NPS. Because the Mineral King deer herd occupies lands managed by three federal agencies, and because CDFG has the ultimate responsibility for regulation of deer numbers, it is imperative that planning should be carried out cooperatively. Such planning should focus both on habitat management and regulation of deer numbers.

Any option that includes increasing the herd to some desired level or maintaining it at current levels should include a provision for harvest. It would make little sense to expend significant sums of public money on any mitigation, compensation, or management proposals that would increase the number of deer without consumptive use. This being the case, the cost of putting more deer in the bag should be considered carefully, particularly if harvest relates to bucks-only proposals. Likewise, there is no possible regulation of numbers by removing bucks alone.

Every effort should be made by management to overcome any time-lag handicaps to mitigation by effecting necessary project modification as development progresses. Mitigation recommendations included here are applicable to a variety of future herd management goals.

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Riparian Revegetation: An Approach to Mitigating for a Disappearing Habitat in the Southwest [1]

Bertin W. Anderson and Robert D. Ohmart[2]

Abstract.--Revegetation of two test plots (20 and 30 ha) has been implemented in riparian habitats along the lower Colorado River in Arizona and California to test the feasibility of using this technique to mitigate habitat losses or for operational enhancement. The data base consisted of plant and vertebrate community data collected monthly for a period of six years. Significant plant and animal correlations developed through community models led to the design of plant communities that predictably would provide maximum wildlife use values.

Plant community development on revegetation sites have thus far produced higher wildlife use values than predicted. Both tree and shrub species are showing high growth rates. Costs vary from site to site and with the contractor, but we found that desert riparian communities can be replaced for about $10,000 per hectare.

Careful consideration must be given to site preparation and machinery required for preparation. Mitigation proposals should be reviewed for possible causes of delay. Care must be taken in selection of a competent and innovative contractor, but once selected, the contractor should be allowed to carry out the work without interference from the contracting agency. Once the mitigation plan has been implemented, careful monitoring should be conducted as long as necessary to insure that predicted results are obtained.

INTRODUCTION

Compensation for wildlife losses from federally supported projects has often been unsatisfying and in many instances impossible as viewed by private, state and federal conservationists. One strategy used by action agencies has been to buy or set aside a tract of good wildlife habitat to mitigate or compensate for losses in the project area. Subsequently, the secondary or replacement site may become a primary site with the agency wanting to buy or set aside another in place of it. This game of "habitat checkers," with wildlife habitat being lost with each move, has led to distrust of action agencies and unsatisfying results. Conservation agencies today are demanding wildlife compensation in place and in kind, when possible.

The rapid loss of riparian habitat in the arid Southwest (Phillips et al. 1964, Lowe 1964, Carothers et al. 1974) combined with its value as a wildlife habitat (Carothers et al. 1974, Johnson and Simpson 1971, Brown, Lowe and Hausler 1977, Hubbard 1977, Stevens et al. 1977, Wauer 1977) has caused much concern among conservation groups. This paper reports on the knowledge we have gained during our studies of riparian habitats and our efforts over the past three years to design and revegetate two experimental sites. If our efforts in revegetating riparian habitats are successful and costs are within a reasonable range, our guidelines and designs can be used for future mitigational efforts, for operational enchancement, and/or habitat improvement.

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PLANNING

Planning for mitigation cannot be done adequately without six basic ingredients (Table 1).

Table 1.--Outline of procedure involved in planning for mitigation.

1. A solid base of data concerning the wildlife in the project area and in the area set aside for mitigation.
2. A thorough analysis of the data.
3. Creation of predictive models with which to create, in theory, a design for the mitigation.
4. Design of modifications required:
    a. Site preparation (e.g., clearing, rootripping, leveling, putting in irrigation system, etc.)
    b. Equipment needs
    c. Costs
    d. A careful analysis of probable delays and what these mean to the overall mitigation effort
5. Implementing design.
    a. Labor requirements
    b. Labor sources
6. Monitoring
    a. Methods of gathering information
    b. Analytical and interpretive techniques
    c. Staff requirements

Before any plans can be made about how to modify an area for wildlife enhancement, there must be a solid data base from both the affected area and the area being set aside for mitigation.

Population data should be collected for all the major groups (birds, mammals, reptiles and amphibians) on a monthly or seasonal basis. In our study we collected monthly and seasonal data for birds and seasonal data for nocturnal rodents as well as general surveys of large mammals and reptiles. In the case of birds, we had the flexibility of being able to analyze populations by month or season. Vegetation measurements (foliage height diversity, patchiness, volume, etc.) were measured once in mature communities not subsequently disturbed in any appreciable way. In communities undergoing succession we measured vegetative parameters twice annually. We also obtained densities of each tree and shrub species in each study plot. If any of these areas were subsequently disturbed in some major way, they were abandoned or considered as a new study area and all parameters were remeasured. All of the censusing procedures used in our study are previously described (Anderson et al. 1977a, 1979).

Birds were found to be extremely responsive to habitat changes and were used as the primary test group. We found that the way birds reacted to the vegetation was very complex. Results radically inconsistent with long-term trends were obtained if only a single year or a single season of population data was considered. Although many avian population studies reported in the literature involve only the breeding season, there is no convincing proof that this is the most important season. We found, for example, that bird populations (including numbers of species as well as densities) reacted to structure (here used broadly to include patchiness, vertical diversity, responses to particular plant species, etc.) less in summer than in other seasons (Anderson and Ohmart 1977a, Anderson et al. 1979). Populations in various plant communities tended to be more similar in summer than in winter (Anderson and Ohmart 1977a, 1977b, 1979). Populations were larger and reacted differently to vegetative structure in mild winters and in summers following mild winters as opposed to cold winters and in summers following cold winters (Anderson and Ohmart 1977a, 1979). The important point is that a study should be of adequate duration to determine how climate affects the ways in which wildlife reacts to vegetative structure. Only then can a realistic evaluation of the impact of a disturbance on that group or a prediction of the outcome of manipulation designed for enhancement be made. Only in a general way were data for a single year sufficient to determine the value of one vegetation type versus another. In both summer and winter of 2 separate years the salt cedar community did not support as large a population of birds as did cottonwood-willow habitats (Table 2). However, a study conducted only in 1977-78 would have minimized differences between the two communities. In fact, differences between cottonwood-willow and salt cedar associations in winter 1977-78 were not

Table 2.--These data indicate that a study encompassing a single year might have led to different conclusions. In 1975-76, a relatively harsh winter, the differences between the salt cedar (SC) and cottonwood-willow (CW) communities in bird densities/40 ha were pronounced and remained very different in summer. In 1977-78, however, the differences between the two community types were not significant ($p>0.05$) and were much less pronounced in summer.

	1975-76	1977-78	Percent Difference
Winter			
SC	46	123	167
CW	122	144	18
Percent Difference	165	17	
Summer	1976	1978	
SC	127	356	180
CW	342	541	58
Percent Difference	169	52	

statistically different. Winter 1975-76 was much harsher than the following winter; the true wildlife use value of cottonwood-willow was more apparent during a severe winter (Anderson and Ohmart 1977a, 1977b, 1978a, 1979).

Over a five-year period we found that patchiness and foliage volume tended to be the most consistent aspects of vegetative structure with which avian densities and diversities were correlated (Anderson and Ohmart 1978b, Anderson et al. 1979, Anderson et al. 1979). Larger populations of several avian species were found in areas with quail bush (Atriplex lentiformis) than in areas of similar vegetative structure and composition, but which lacked quail bush. The presence of mistletoe (Phoradendron californicum) was important to fruit-eating birds in winter, while ink weed (Suaeda spp.) and wolfberry (Lycium spp.) were found to be important to Sage Sparrows (Amphispiza belli) and post-breeding populations of Phainopeplas (Phainopepla nitens), respectively (Anderson and Ohmart 1978a, Anderson et al. 1979).

On the basis of these findings we developed a plan for modifying vegetation for the enhancement of wildlife (Fig. 1, Table 3). The sites on which this plan is being implemented include one of about 30 ha of dredge spoil. The soils in this area are mainly sand on which little vegetation has developed over the past 25 years. A second site of about 20 ha consisted primarily of salt cedar (Tamarix chinensis). This exotic Old World species was cleared and is being replanted with native vegetation (see Fig. 1).

Salt cedar has formed dense stands within the levees and seriously restricts high water flows, making it highly undesirable. Because it is not of consistently high value to a vast majority of avian species in the lower Colorado River Valley (Cohan et al. 1979), large tracts can be replaced with native species with a community design less restrictive to water flow but with higher wildlife use values than salt cedar. Salt cedar has to a larger extent, replaced native vegetation in the valley (Ohmart et al. 1977).

Before implementing the revegetation plan, a number of considerations relative to site modification had to be considered. Since salt cedar sprouts rapidly from root stock, ripping of the roots had to be undertaken and was about 90 percent effective. The area then had to be leveled.

In desert riparian areas, which are subject to prolonged and extreme desiccation, it is imperative to insure that the roots of the new vegetation gain access to the water table. Root penetration to the water table is prevented or seriously impeded by dense soil layers (for summary and references see Anderson and Ohmart 1978b). Backhoeing or augering a hole for each tree insures a uniform soil texture to the water table. Finally, irrigation is required until the roots reach the water table.

Expertise in agroproduction was invaluable to our efforts, especially local farmers and extension service professionals. These consultants have provided information on water table depth and soil structure and chemistry.

Table 3.--Site revegetation diversity after clearing salt cedar. The area has a total of 30 subplots each with an area of 0.08 ha.

Number of subplots dominated by	
Cottonwood-willow	11
Honey mesquite	7
Quail bush	9
Number of subplots with	
Cottonwood-willow present	21
Honey mesquite present	23
Palo verde present	13
Quail bush present	17
Only cottonwood and/or willow	2
Only quail bush	1
Only honey mesquite	2
At least 1/4 bare soil	19
No bare soil	11
Number of plots immediately adjacent	
Vegetation dominated by salt cedar	16
Road and main irrigation canal	6
Small ponds	3
Agricultural situation	1

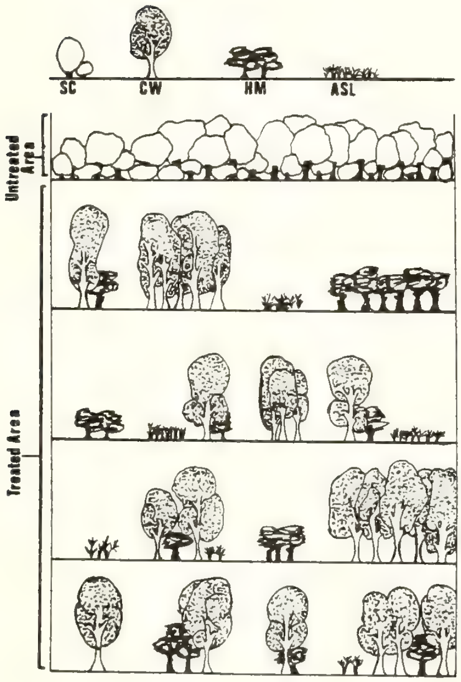

Figure 1.--Schematic illustration depicting vegetative diversity in a model designed for enhancement of wildlife. Note three fire lanes to be maintained in the area.

Serious consultation can save much time and expense and can help avoid failure. Experts who have agreed to serve as consultants and their areas of expertise should be listed in mitigation proposals.

Since revegetation efforts are expensive, site preparation costs should be kept minimal but not slighted. Irrigation systems, when required, should be relatively inexpensive and simple to install and maintain. Consultation with local irrigation experts (area farmers, agricultural extension agents, irrigation suppliers, etc.) can help avoid unnecessary costs when irrigation is required.

A carefully prepared list of required machinery should be included in mitigation plans. Again local expertise can be useful. For example, we needed a bulldozer capable of removing trees up to 20 feet tall and of pulling a root-ripper about 2 feet below the soil surface, a mechanical auger capable of drilling 3 to 4 m, a hydraulically controlled blade for leveling, and a tractor large enough to pull the blade. Local expertise provided specific information relative to the size of bulldozers and tractors required. Funds for renting or buying this equipment should be provided to the contractor. We cannot overemphasize the importance of including in any mitigation plans a detailed assessment of the equipment needed and a careful documentation of machinery specifications. Delays and higher costs are inevitable without careful planning.

We found that clearing and operating ordinary farm machinery in relatively rough terrain leads to a lot of mechanical failure. Schedule a full day of downtime for every full day of operation if the work is being done in relatively rough terrain. Even on dredge spoil, when power equipment is required, delays due to mechanical breakdown are frequent.

CONTRACTING

The agency responsible for mitigation may choose to have the work carried out under contract, preferably by a reputable contractor of high integrity. Mitigation is expensive--often very expensive. Plans for mitigation for which adequate funds are not available should not be proposed, or if proposed, the shortage of funds should be explicit. Therefore the contracting agency should select a contractor whose mitigation proposal has a high chance of success rather than selecting the cheapest bid with little chance of success. Where competence and success are equal, the contractor with the lowest bid should receive the work.

The contracting agency should allow the contractor total freedom but make field checks. However, persistent interference with elements of design, implementation, and maintenance can curtail progress.

IMPLEMENTATION

The contractor should have sufficient funds to either buy or rent all equipment necessary to implement the design. Any other arrangements may be totally unsatisfactory relative to the progress of the plan.

Timing of planting has been found to be critical in our area. In desert riparian areas the winter is the best time to proceed with planting. Evaporation is much lower; thus thorough saturation of the soil from the surface to the water table is easier. By the summer only enough water is needed to maintain a water-saturated soil column, plus that used by the plant. Trees or shrubs planted in the winter will have a developed root system and suffer fewer side effects should the irrigation system fail. In our revegetation efforts we have found that cuttings from wild stock started in a nursery have highest survival and growth rates. Plants from seeds germinated on site were hardier than those germinated in a nursery and transplanted (Anderson et al. 1979).

MONITORING

Initial revegetation efforts should be carefully monitored. We census birds monthly and rodents seasonally; vegetation growth is measured quarterly in our experimental areas. Each tree is marked with a numbered metal tag. Growth rates in a variety of soil types under various watering and fertilizing tests can be documented. Evaluations of predicted and observed results should be made frequently. Monitoring is critical; there should be adequate staff for data collection, thorough analysis, and interpretation.

Monitoring methodologies should be kept constant throughout data gathering. After a period of time, it might be possible to predict that if the vegetation is developing according to design and wildlife is reacting in ways close to that predicted, all will go according to plan until the vegetation reaches maturity. Pioneer efforts should be monitored until it is evident that the desired objectives have been achieved. Less intensive monitoring efforts may be possible as experience and knowledge are gained.

SUCCESS OF EXPERIMENTAL REVEGETATION PLOTS

On our experimental plots, palo verde (Cercidum floridum) honey mesquite (Prosopis velutina) willow (Salix gooddingii) and cottonwood trees (Populus fremonti) grew an average of 112 cm, 88 cm, 6 cm, and 38 cm, respectively, in three months (Anderson et al. 1979). Combined survival for these trees was 76 percent and was greatest (94 percent) for cottonwood. In January 1979, we planted 2,000 trees. After five months, survival was more than 95 percent, growth rates have exceeded expectations and it appears that by mid-summer many of these trees will be able to survive without additional watering.

Shrubs have also responded well. Wolfberry, transplanted in January, leafed out in spring, and many produced fruit in May.

Avian densities remained low for six months after planting in March 1977. By November of that year the number of birds per 40 ha exceeded, by 50 percent or more, densities found in the most abundant riparian vegetation types. Most of these birds were seedeaters and were consuming seeds of annuals which grew as a result of our irrigation (Anderson et al. 1979). Indications were that rodents, rabbits and snakes also increased in numbers.

During the first six months of revegetation the number of avian species observed during any single month was less than half the number observed in typical riparian vegetation. By February 1978 (11 months later) as many or more species were found on the revegetation plot as in typical riparian stands (Anderson et al. 1979).

ECONOMIC FEASIBILITY OF REVEGETATION

An effort to determine economic feasibility of revegetation on a relatively large scale, perhaps 400 to 500 ha, has been a major objective of our experimental efforts. Answers to such questions are largely value judgments. However, it seems clear that revegetation efforts are not likely to be considered inexpensive. In our judgment a high degree of success should be the major goal. To insure success, the cost of essentials cannot be reduced. Manpower requirements should be viewed as a worthwhile investment; there will be a greater return on the dollar with too much manpower than if there is a shortage. In the desert Southwest, root-ripping and augering are essential in site preparation.

Nonetheless, reduction of costs can be accomplished by using inexpensive but effective irrigational systems. Local farmers or extension service personnel have the best insight into the least expensive but most effective systems.

Although augering holes for every tree is costly, perhaps $200 per ha, it is essential to insure plant survival once the irrigation system is removed. Augering also reduces the time trees need to be watered from three or more years to perhaps eight to ten months. This means use of much less water and reduced irrigation costs.

In our estimation, revegetation of a 400 ha plot in the lower Colorado River Valley, involving the clearing of salt cedar, would require ten years (3 years for clearing and planting, 7 years for monitoring) and would cost between $3.5 and $4.5 million. Those who place high values on wildlife might view this as an inexpensive price to pay. Others, whose values lie elsewhere, might view such an expense as exorbitant. Clearing an equivalent area for agriculture and farming it for a total of ten years would cost about four to six times this amount. The returns from the two contrasting efforts cannot be compared in monetary terms.

In summary, we present a promising technique for mitigating for southwestern riparian habitats in kind and place. Though results are preliminary, the wildlife use values are already higher than the predicted values. Costs may seem high to some, but if a lesson is to be gleaned from our data it is this: action agencies should explore all alternatives prior to destroying a reach of valuable riparian habitat. Should it be necessary to destroy it they should be prepared to meet the high cost to replace it in kind and place.

ACKNOWLEDGEMENTS

We wish to thank Nancy Jackson for typing the rough drafts of the manuscripts and Luanne Cali for typing the final draft. We are grateful to Jane Durham, William Butler and Susan Cook who offered suggestions concerning improvements of the manuscript. Personnel from the Extension Service, University of California at Riverside provided invaluable advice both on and off the site. Without their help and that of local farmers we would still be mired in dredge spoil sand. We are grateful to the U. S. Bureau of Reclamation, Boulder City Regional Office, for their long-term interest in, and funding for our research under Contract No. 7-07-30-V009. The U. S. Fish and Wildlife Service in Albuquerque, New Mexico equally supported and funded the effort under joint funding through the Bureau of Reclamation.

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Public Land Management Opportunities for Mitigation[1]

John E. Crawford, Edward C. Roberts, and Denise P. Meridith[2]

Abstract.--Scattered tracts of Federal public lands administered by the Bureau of Land Management provide islands of habitat diversity and opportunity for our Nation's wildlife. Public lands are managed under multiple-use charter which specifies commodity production as well as protecting environmental values. Special opportunities are identified for protecting and enhancing diversity through land-use planning, management, and habitat manipulation.

The Bureau of Land Management does not fit into the classical concept of fish and wildlife mitigation nor does it discharge its mitigative responsibilities in the usual way. The Bureau is not a construction Agency, and only in uncommon circumstances involving water related projects does it become involved with more routine mitigation procedures. But, at the same time, every action we take or don't take on the public lands we administer affects wildlife and its habitat--good, bad, or otherwise. Rather than some drastic, large-scale, and eye catching actions which are obvious mitigation events, BLM's role fits in with land changes more salient, e.g., rights-of-way for roads and pipelines, oil and gas leases, and the harvest of timber, posts, and firewood.

In traveling to this meeting, most of us observed broad changes to the landscape. Some may have gone by unnoticed because of their commonality. Among these were bigger and better airports, expanded highway networks--like Interstate 25--that comes right by Fort Collins, suburban residential developments, shopping centers, recreation development, mountain homesites--like in Vale, and extensive agricultural areas typical to the eastern plains. This represents what's happening across this great land, the impacts upon wildlife habitat and the needs for mitigation. Arguing the pros and cons of this development is best left to forums other than this Symposim, but the net effect on wildlife is a continuing and substantial loss in the amount and diversity of their habitat.

Now let's focus on the 417 million acres of public land for which BLM is responsible. Much of this provides wildlife habitat for most of the Nation's desert bighorn sheep and antelope, and significant numbers of caribou, brown and grizzly bears, moose, mule deer, fish, and a host of nongame wildlife. Most of us meeting here in Colorado identify public lands with the West, and we usually envision them in terms of large land blocks. But few are aware of the 59,000 acres of scattered public land tracts extending from Maine to Florida, and from the gulf of Mexico to the Great Lakes States (2,800 islands in Minnesota, Michigan, and Wisconsin). Species diversity extremes on the public land ranges from the alligator and polar bear to the bald eagle and javelina. The sensitivity of such diversity and habitat variety to even the most routine land management action demands BLM's specific attention.

At this point, a frame of reference must be established as to the important role our public lands can play in mitigating or offsetting some of our national losses in habitat amount and diversity. Similar opportunities may exist on other Federal lands--National Forest, Wildlife Refuges, National Parks, and Military Reservations. In addition, State lands may provide an added dimension to opportunities for maintaining faunal and floral diversity. For example, here in Colorado, there are over 2 1/2 million acres of school lands plus those managed by the Colorado Divisions of Wildlife and Parks and Recreation. It would be unfair to imply that management of the public lands could or should be keyed solely to maximizing wildlife production to mitigate national trends in declining habitat quantity and quality. This management approach is reasonably expected on lands administered by single-use agencies, such as the Fish and Wildlife Service and State wildlife agencies. By its legislative mandate, the Federal Land Policy and Management Act of 1976, the Bureau of Land Management administers the public lands for all resources under the principles of multiple use and sustained yield.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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In essence, multiple-use management involves a series of trade-offs and compromises as determined by public needs and the relative values of the resources. Multiple-use management for a specific tract of land is not necessarily directed toward the maximum production of all resources, but often production of one resource over others present. In achieving this, the less prominent resources must still be considered and protected while allowing the priority resource to reach its full potential. This is a form of mitigation in itself and requires constant Bureau effort on a daily basis.

Several laws passed during the late 1960s and 1970s have given BLM the latitude and initiative to manage, enhance, and--where necessary--completely preserve wildlife habitat, whether it is the priority resource onsite or not. These laws include the National Environmental Policy Act, the Endangered Species Act of 1973, the Sikes Act as amended, the Federal Land Policy and Management Act, and the Public Rangeland Improvement Act.

The Bureau of Land Management today has an opportunity, without precedent in our history, to enter into a new era of public service It is an era in which the fish and wildlife resource and its management are an integral part of multiple use with the concept of mitigation "built in" rather than an afterthought. Let us look at some example:

Enactment of the Federal Land Policy and Management Act specifies fish and wildlife development as one of the six major or principal uses of the public lands. The wildlife resource is thus considered from the outset. Under this new charter, we are beginning full implementation of a new system for "Areas of Critical Environmental Concern." These are special places that require equally special management attention. They will contain important and critical fish and wildlife resources and the natural systems and processes that support them. Areas of Critical Environmental Concern will not necessarily be places where no development or wildlife habitat improvement can occur. Instead, where development or improvements are permitted, they must be compatible with the purposes for which they were originally designated as Areas of Critical Environmental Concern.

BLM is now into full implementation of our responsibilities to recommend roadless areas on the public lands that have wilderness characteristics for consideration by Congress for inclusion in the National Wilderness System. Wilderness is not only a major program itself, it also offers benefits to those species of fish and wildlife, dependent on more remote-type habitat, such as the falcon, eagle, bighorn sheep, mountain lion, and grizzly.

Enactment of recent Sikes Act amendments provide authority for major improvements in habitat conditions. Through its proviso for cooperative programs with State wildlife agencies, the Sikes Act affords an excellent vehicle for State-Federal habitat management and "automatic mitigation" built in to all related land actions within formally designated habitat areas. Memoranda of Understanding with 11 Western States set forth how BLM and the States will work together cooperatively for wildlife conservation and rehabilitation programs under authority of the Sikes Act. Results of these programs for wildlife and its habitat have been outstanding. To date, 20 million acres of public land are under habitat management programs, most of which have been implemented under authority of the Sikes Act. This is helping to offset and, in a sense, mitigate habitat losses elsewhere.

Enactment--just last year--of the Public Rangeland Improvement Act establishes for the first time a national policy to improve the productivity of the western range for all beneficial purposes, including watershed protection and vegetation for wildlife, as well as domestic livestock. This Act further authorizes a year-by-year investment schedule for on-the-ground work to be accomplished.

As a result of these new laws and State-Federal agreements, we now, for the first time, really can approach habitat management and mitigation as they should be approached . . . through careful forethought in the Bureau's planning system and environmental compliance procedures.

Good inventories are the keystones for having our wildlife resources properly considered in land-use planning and in meeting environmental commitments, no matter what level of mitigation is involved. Before wildlife values can be enhanced, protected, or mitigated, it is imperative to know what wildlife resources are present, where they are, and how much habitat exists. With this prerequisite met, wildlife stands a much better chance to compete in the allocation of resources and will fare better when tradeoffs are made. For example, knowledge of animal concentration areas and seasons of use will identify conflicts and permit equitable allocation of vegetation to wildlife as food and cover, and as forage for domestic livestock, wild horses and burros.

To summarize BLM's approach and involvement with mitigation, we must consider six major factors related to land actions and wildlife habitat:

1. Habitat diversity and species occurrence;

2. Maximum population numbers in balance with habitat;

3. Understanding the consequences of alternative land management actions as they influence habitat and, thus, the number and varities of species present;

4. Realistic economic costs and benefits;

5. Compliance with laws and regulations; and

6. Technical feasibility or scientific state-of-the-art.

These six factors are an integral part of the Bureau's two major roles in wildlife mitigation. In our first role, we must recognize the broad national importance of the public lands in maintaining faunal and floral diversity. This is particularly critical where adjacent land-use practices have so altered the landscape that the public lands provide the only natural remnants of habitat diversity. In our second role, we must carefully analyze the consequences of alternatives for land-use development and production, then select the least harmful alternative and develop the best stipulations and safeguards possible to protect wildlife and its habitat. Fulfilling both roles properly mandates that we manage wildlife habitats in a carefully preplanned sense to offset losses to habitat quantity and quality through the tradeoff process in multiple-use management.

The words "multiple use" have been used freely in this presentation. To those of us who are wildlife oriented, the words "multiple use" often mean protect and manage for the wildlife values present at any cost to other uses or resources production. Other users share this same viewpoint for their special interests.

Multiple use should also surface a point of caution for us all. Public land management is in an era of conflict and opposing advocacies, and the Bureau usually finds itself in an arbitration role between indignant and often outraged user groups. Nobody wants to give, nobody seeks compromise, and--too frequently--the controversy spills over into the courtroom; and the judge becomes the final authority in resource management. Biological and resource issues then become legal issues and mitigation moves from land action plans to lawbooks.

We need better procedures for settling environmental disputes than dueling pistols at dawn or telling it to the judge. The process, as it is now, is not sensible to constructive resource management nor does it always result in the proper mitigation for the impacted wildlife habitat at stake.

If my presentation denotes optimism for wildlife, habitat, and mitigative efforts, that is because I intended to do so. But, I also recognize that mitigation is not easy, as we face expanding public pressures for resource use and commodities. Energy sources on the public lands will be developed and energy will be produced. This includes the full spectrum of energy sources--gas, oil, geothermal, and coal. It's no longer a question of if, but when. It's also not a question of whether mitigation will occur, but how can we do it best to reach an equitable balance between wildlife values and development.

Estimating Stream Macrobenthos Benefits from Low Flow Augmentation[1]

Elwin D. Evans[2]

Macrobenthos was sampled in 1977 in the Sturgeon River of Michigan's Upper Peninsula to determine the impacts of a hydroelectric facility and to estimate benefits from low flow augmentation. Biomass was reduced 76%, number of taxa by almost 25% and average organism size by 73%. Low flow augmentation from 0.406 m^3/sec to 2.772 m^3/sec would increase biomass at least 39%.

INTRODUCTION

A section of the Sturgeon River in Michigan's Upper Peninsula (fig. 1) was sampled in 1977 to determine the impacts of the Prickett Dam's hydro facility on stream macrobenthos in the first 14.6 km of stream immediately below the dam. Benefits to macrobenthos from increased minimum flows were also estimated. Results of this study were presented at a Federal Energy Regulatory Commission hearing, September 14, 1978 as part of the Michigan Department of Natural Resources case for low flow requirements in the license for this facility (Evans, 1978).

Prickett Dam was constructed in 1931 and has since been operated as a peaking facility. When not generating electricity, only leakage flows are bypassed, except during spring breakup in late March, April and early May, when excess water is bypassed via an overflow structure. Leakage was 0.406 m^3/sec at the beginning of the study (fig. 2). When generating, flows are in excess of 17.5 m^3/sec (fig. 3). Power generation occurs twice daily during the work week.

The Sturgeon River basin is 1888 km^2 in area with 896 km^2 above Prickett Dam. Flow into the impoundment has been estimated to equal or exceed 1.96 m^3/sec 99.9% of the time. Below the dam the river flows 72 km north to Portage Lake which transects the base of the Keweenaw Peninsula. Water Quality monitoring data characterize this river as a clear, tea colored, soft water river with moderate

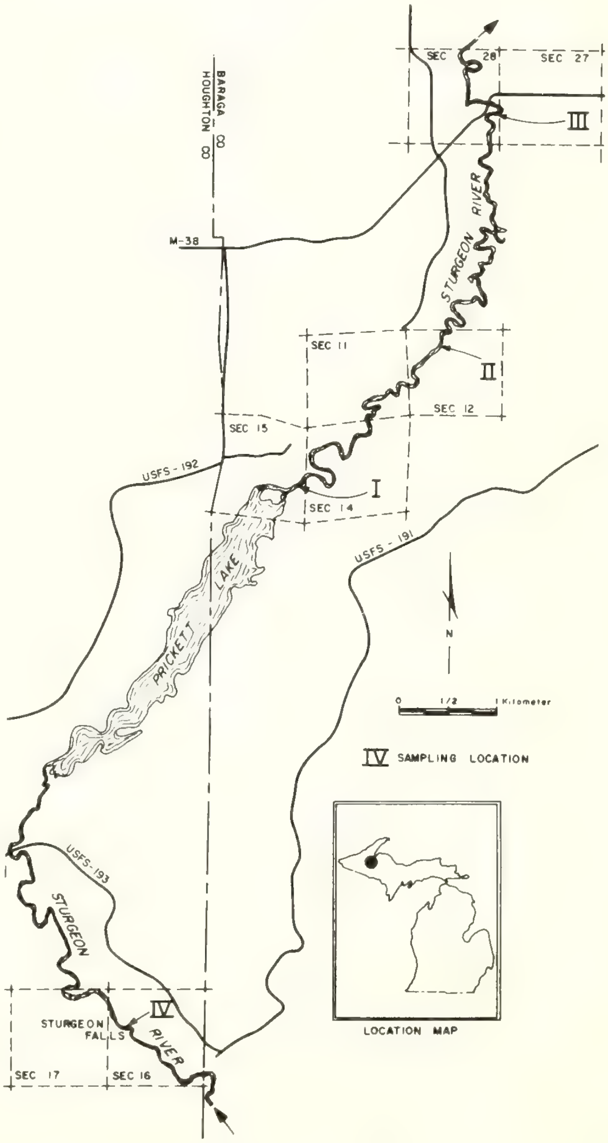

Figure 1.--Macrobenthos sampling locations on the Sturgeon River, Baraga and Houghton Counties, Michigan, June 20, 1977.

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[1] Paper presented at the Mitigation Symposium, National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Fort Collins, Colorado, July 16-20, 1979.

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nutrient levels and is typical of many streams in the region. In the 14.6 km stream reach immediately below the dam, the river falls almost 18 meters or about 1.2 m/km. Due to this high stream gradient, substrate in the study reach consists largely of rubble and gravel, although some sand exists. Downstream of the study area, sand is the dominant substrate. The stream reach in the study area serves as a fish spawning area and source for fish food organisms. Most recreational activities, such as fishing and canoeing, take place downstream of the study area and Highway M-38.

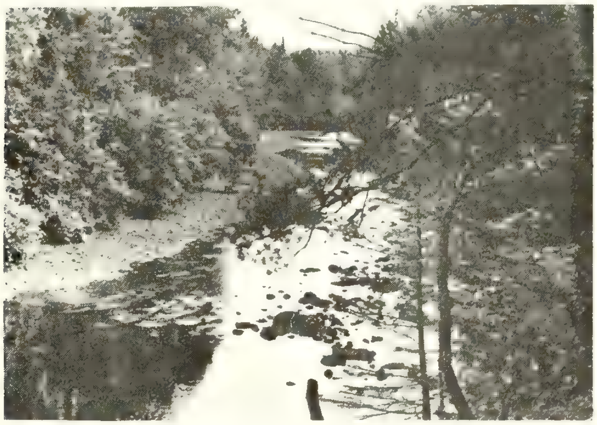

Figure 2.--View of Sturgeon River, Baraga County, Michigan, 300 meters below Prickett Dam powerhouse with gates closed.

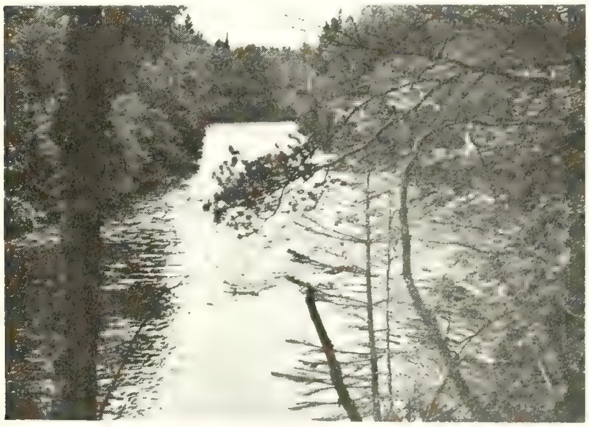

Figure 3.--View of Sturgeon River, Baraga County, Michigan, 300 meters below Prickett Dam powerhouse with gates open.

METHODS

Macrobenthos

On June 20, 1977 three macrobenthos sampling stations were sampled below Prickett Dam. A fourth station was sampled upstream of Prickett Lake (fig. 1). At each station below the dam, five samples were collected with a 20 cm pipe sampler at points equidistant along a transect across the stream. Stream conditions above the lake made sampling along a transect impossible. Five samples were taken in substrate and at depths similar to downstream stations. All materials were removed from the sampler to a depth of approximately 10 cm and placed in a sieve bucket with a bottom of U.S. Standard 30 mesh screen (590 micron openings). The materials remaining in the sampler were sieved with a fine mesh aquari net. Sieving continued until no additional animals were collected. Animals were washed fro larger substrate particles which were discarde All collected animals with the finer materials were placed in quart jars and preserved with formalin.

A qualitative macroinvertebrate sample was collected at each station with a triangula dipnet with a mesh 1.0 mm from center of threa to center of thread. Collected materials were placed in the sieve bucket. Larger animals were removed, placed in a jar with about two-thirds of a quart of the finer materials, and preserved with formalin.

Two pipe samples were also taken in dewatered areas at each station below the dam. These samples were washed in the sieve bucket and observed in a field for macroinvertebrates None were found.

All animals were identified to the lowest taxonomic category possible without slide mounting. Macroinvertebrate volume was determined for all pipe samples to the nearest 0.1 by volumetric displacement in a 15 ml conical centrifuge tube. Macroinvertebrate volumes were multiplied by 1.1, their approximate density to obtain wet weight in grams per sample. Biomass in g/m^2 wet weight was obtained by multiplying sample wet weight by 31, the correction factor for expressing pipe sampler values on a square meter basis.

Stream Flows and Cross Sections

Stream cross sectioning was undertaken at the same stations below Prickett Dam as macrobenthos sampling. Total channel width and stream width at leakage flow from the dam of 0.406 m^3/sec were initially determined after approximately 60 hours had passed since power was last generated. This was representative of weekend substrate dewatering. Over the next 36 hours flows of 0.868 m^3/sec, 2.100 m^3/sec and 2.772 m^3/sec were released through the dam by Upper Peninsula Power Company personnel. Stream widths and cross sections were determined at each station for each increased flow release from the dam.

RESULTS

Low Flow Augmentation

Results of augmenting low flow on increased wetted stream bottom are given in Table 1. At Leakage flows of 0.406 m^3/sec, 27.0 ha of wetted stream were estimated to exist. Peak generating flow releases of 17.500 m^3/sec result in approximately 83.7 ha of wetted stream bottom. Study flow releases of 0.868 m^3/sec, 2.100 m^3/sec and 2.772 m^3/sec resulted in increased wetted stream bottom area by 0.9 ha, 7.5 ha and 0.6 ha, respectively.

Table 1.--Stream widths in meters at various flows through Prickett Dam June 20, 1978 and estimated stream surface hectares in the first 14.6 km below the dam.

Station No.	I	II	III	hectares
Flow m^3/sec				
0.406	17.7	19.8	18.0	27.0
0.868	19.8	20.1	19.5	27.9
2.100	26.2	21.1	23.5	34.5
2.772	28.4	21.7	27.1	37.6
7.500	35.1	26.2	57.3	83.7

Macrobenthos

Qualitative macrobenthos sampling esults are summarized in Table 2. More than 0 taxa were found at each of the three tations below the dam. Forty taxa were ound above the dam (Station IV). More than 0% of all macrobenthos taxa below the dam ere stoneflies, mayflies and caddisflies hile 60% were in these categories above the am. These data are similar to the pipe ampler data in terms of the numbers of kinds f taxa collected at each station. A erious water quality problem was not indicated y the data.

able 2.--Number of taxa in major macrobenthos categories from qualitative samples.

tations No.	I	II	III	V
toneflies	1	2	2	3
ayflies	3	7	6	7
addisflies	6	5	6	14
ipterans	14	7	11	7
thers	8	10	6	9
otals	32	31	31	40

The more than 20% decrease in total axa indicates impacts of high flow variations nd water temperatures on macrobenthos. addisflies averaged less than six taxa per tation below the dam and 14 taxa above it. milar changes are evident in the quantitative esults. Cool or cold water genera such as *Epeorus*, a mayfly and *Acroneuria*, a stonefly, and the caddisfly taxa *Glossosoma*, *Arctopsyche Rhyacophila*, and Psychomyiidae were absent below the dam (Philipson, 1955). Net spinning caddisflies, other than *Arctopsyche* and the Psychomyiidae, found above the dam and absent below it, were *Dolophilodes* and the Philopotamidae. Net spinning caddisflies require minimum water velocities, which are probably not met by leakage flows through the dam. Water temperatures below the dam would likely reflect ambient air temperatures because water in the wide shallow channel would heat and cool rapidly. Water temperatures of 25°C on weekends during the summer when power is not generated could easily be reached, if not exceed. Ice formation during low flow periods in the water and ice drift during power generation would exert another extreme stress on macrobenthos. Further study might reveal which factor caused the observed changes more precisely, although it is obvious that flow velocity and water temperatures interact.

Quantitative benthos sampling results are summarized in Table 3. Almost the same number of macrobenthos taxa (31) were found at each station below the sam in the quantitative samples as in the qualitative samples. Forty-four taxa were collected above the dam in quantitative samples, an increase of four taxa over the qualitative sample. This results from using a net with a smaller mesh size when using a pipe sampler.

Statistical analysis of the data using Tukey's test at the 5% significance level are shown in Table 4. No significant differences were found between average number of taxa per sample per station or the average mean diversity. Average macrobenthos density of 5338 organisms/m^2 at Station I were significantly different from the other three stations which did not differ from each other. However, average biomass of 21.82 g/m^2 wet weight at Station IV above the dam was significantly greater than average biomass at the three stations below the dam which were not significantly different from each other. Average biomass below the dam was 5.23 g/m^2 wet weight. Average organism wet weight (average biomass ÷ average density) was 0.01013 g above the dam and averaged 0.00273 g for the three stations below it.

Composition of macrobenthos communities exhibited marked changes and trends below Prickett Dam. At Station I, chironomids composed 56 percent of the macrobenthos density of 5338 organism/m^2, and had the smallest average wet weight per organism of 0.00171 g. Short filamentous algae of moderate density grew on larger substrate particles at this station in response to nutrient releases

Table 3.--Summary of macrobenthos 20 cm diameter pipe sampler data as totals per station or average estimates per m^2 from the Sturgeon River, Baraga and Houghton Counties, Michigan, June 20, 1977.

Station No.	I	II	III	IV
Total Taxa				
Stoneflies	0	2	2	3
Mayflies	2	4	7	7
Caddisflies	8	4	3	16
Chironomids	8	6	6	5
"Others"	14	14	12	13
	32	30	30	44
Density				
Stoneflies	0	12	19	87
Mayflies	87	254	694	446
Caddisflies	260	81	31	916
Chironomids	2970	521	223	775
"Others"	2021	366	385	361
	5338	1234	1352	2585
Percent				
Stoneflies	0	1	1	3
Mayflies	2	21	51	17
Caddisflies	5	7	2	35
Chironomids	56	42	16	30
"Others"	<37	<29	<30	<14
Wet Weight (g)	8.18	3.41	4.09	21.82
Sample d	3.11	3.29	3.13	3.81
Station $\bar{d}$	3.40	4.25	3.70	4.63
Wet Weight x 10^{-3}/ Organism	1.71	3.24	3.22	10.13

Table 4.--Tukey's test at 5% significance level on quantitative macrobenthos data from the Sturgeon River, Baraga and Houghton Counties, Michigan, June 20, 1977. Stations I, II and III below dam. Station IV above dam.

Average no. taxa/sample/ station	IV	I	III	II
	21.2	18.4	13.6	13.4
Average mean diversity ($\bar{d}$)	IV	II	III	I
	3.80	3.28	3.13	3.10
Density m/^{2}	I	IV	III	II
	5338	2585	1352	1234
Biomass g/m^2 wet weight	IV	I	III	II
	21.82	8.18	4.09	3.41

from the dam and probably serve as a chironomid food source. This is commonly observed below reservoirs and hydro facilities especially those with a bottom discharge. No stoneflies were collected in the quantitative sample and mayflies densities were the lowest of the four stations.

Stoneflies and mayflies increased downstream at Station II and III but caddisflies decreased as a result of the fewer net spinning filter feeding Hydropsychidae. Chironomids also decreased markedly. Filamentous algae was not observed.

Station IV, above Prickett Lake had a very diverse caddisfly fauna with 16 taxa and densities of 916 organisms/m^2. Furthermore, a better balance existed between the various major taxa than at the other station.

No macroinvertebrates were observed in dewatered substrate samples nor beneath larger rocks along the shore at any of the three stations below the dam. Fluctuating shorelines are difficult for macrobenthos to colonize and inhabitat (Brusven, 1976).

Macrobenthos benefits from low flow augmentation would result in increased stream velocities and continuously wetted stream bottom. Biomass estimated at 5.23 g/m^2 in the 27.0 ha below the dam at leakage flows give a total macrobenthos biomass of 1413 kg. Assuming macrobenthos biomass to increase in proportion to increased available habitat, discharges of 0.868 m^3/sec, 2.100 m^3/sec and 2.772 m^3/sec would result in biomass increases to 1459 kg, 1804 kg and 1967 kg, respectively. These should be considered conservative biomass estimates from low flow augmentation because benefits to macrobenthos from increased velocities could not be determined.

DISCUSSION AND CONCLUSIONS

Studies of hydroelectric generating facility impacts on stream macrobenthos have seldom been undertaken, although many investigations have been completed regarding fisheries (Geen, 1974; Stalnaker and Arnette, 1976). Based on Surber samples, Radford and Hartland-Rowe (1971) found macrobenthos densities reduced from 326 organisms/m^2 at their control station to 174 organisms/m^2 below a hydro facility on the oligotrophic Kananaskis River and biomass decreased from 2.91 g/m^2 wet weight to 1.37 g. Trotzky and Gregory (1974) found 19 genera of macroinvertebrates above a hydro facility and 11 downstream of it. These studies show macrobenthos community shifts similar to those found in the Sturgeon River below Prickett Dam where densities (Station II and III), biomass and the number of taxa declined. I have not found any reports wherein the effects of either hydro facilities or reservoirs on average macroinvertebrate size or weight have been considered, even though this would be an important parameter for assessing a forage base for fish (Bisson, 1978). A macrobenthos community with individuals of small average size or weight usually exists in pollution stressed streams. Only small fish were collected in fish population assessments below the dam with an average length of less than 20 cm and no fish greater than 23 cm (Evans, 1978).

Extensive flow variations below hydro facilities are perhaps the greatest detriment to macrobenthos. Drift of macrobenthos is markedly increased by increased flows (Elliot, 1967; Pearson, et al., 1968; Anderson and Lehmkuhl, 1968; and Radford and Hartland-Rowe, 1971). The 43 fold increase in flow, twice daily during the work week, below the Prickett Dam and resultant dewatering of 67% of the streambed in the study area is undoubtedly the major factor in reducing macrobenthos taxa by more than 20%, biomass by 76% and decreasing average individual macroinvertebrate weight by a factor of 3 or more.

The Michigan Department of Natural Resources has requested that a low flow of 2.772 m^3/sec be released from Prickett Dam at all times to mitigate the effects of this operation. If this is a stipulation in the License issued by the Federal Energy Regulatory Commission, at least 39% more macrobenthos would exist in the study area. Furthermore, the macrobenthos benefits are only part of the overall benefits that would be realized from low flow augmentation. Anandromous ish spawning success, resident fish populations, ishing and boating would also be improved.

Mitigation of impacts from all types of ams and their impoundments will be sought in he future as part of environmental impact tudies and licensing. Studies of aquatic iota for either mitigation or litigation urposes should be always include biomass stimates of important organisms and some stimate of their production. The quality or vailability of biomass to organisms of nterest should also be evaluated in aquatic cosystem studies. Without these types of asic data, resources of little apparent alue, such as macrobenthos cannot be converted o resources of high value, such as fish. If alue for aquatic biota and their function annot be established, mitigation or litigation n behalf of these resources is difficult and nlikely to be successful.

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Limnological Considerations in Reservoir Operation: Optimization Strategies for Protection of Aquatic Biota in the Receiving Stream [1]

James V. Ward[2] and Jack A. Stanford[3]

Abstract.--The plethora of regulated streams necessitates a greater understanding of biological effects of various operational schemes if the receiving stream environment is to be optimized within limits posed by other legitimate demands on the water. Limnological concepts and principles of stream ecology are integrated to address optimization strategies to protect the aquatic biota in streams below large dams.

INTRODUCTION

The majority of the world's major rivers no longer freely flow from headwaters to the sea. Rather, dams of various types and sizes, constructed for various purposes, have changed long sections of lotic (running water) systems into lentic water bodies (artificial lakes). The conditions prevailing in reservoirs and the ways in which they differ from natural lakes have been well documented (see e.g. Ackermann et al. 1973, Hall 1971, Lowe-McConnell 1966, Obeng 1969, Ridley and Steel 1975, Baxter 1977). Only recently, however, has ecological research been directed toward modifications occurring in regulated stream reaches below dams (Ward and Stanford 1979). The plethora of regulated streams necessitates a greater understanding of the biological effects of various operational schemes if the receiving stream environment is to be optimized within the limits posed by other legitimate demands on the water.

It is the purpose of this paper to integrate limnological concepts with principles of stream ecology in examining potential problems in regulated streams, and thereby to address ameliorative measures to protect the biotic communities of these modified lotic systems. Following a brief description of natural stream ecosystems, the various modifications resulting from an upstream impoundment will be discussed with suggestions for amelioration of biologically adverse conditions. Unless otherwise stated, discussion will be limited to deep holomictic reservoirs which thermally stratify.

NATURAL STREAM ECOSYSTEMS

The biota of high-gradient streams in the temperate zone have an evolution history linked to cool temperatures, high dissolved oxygen, relatively rapid current and a rocky substrate (Hynes 1970). Their respiratory physiology, feeding mechanisms, behavioral responses, and life histories are generally dependent upon conditions in natural streams. As unregulated streams flow from headwaters to lower reaches, major changes in environmental conditions are accompanied by corresponding changes in the biota (Cummins 1979, Illies and Botosaneanu 1963).

Water temperatures of headwater reaches are generally cool and relatively constant due to shading and groundwater inputs. Diel and annual thermal ranges increase downstream until the heat capacity of the larger river results in enhanced thermal stability.

Headwater reaches generally exhibit high current velocity and turbulent flow, whereas the current is often slower and the flow more laminar in lower reaches. Unregulated streams are characterized by great temporal variations in discharge which may be predictable (e.g. spring runoff), or which result from specific meteorological events (e.g. spates).

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There is a general downstream decrease in the size of substrate particles accompanied by an increase in turbidity. In reaches where the interstices between substrate particles are periodically flushed of finer materials a hyporheic zone develops. The importance of silt-free substrate interstices as incubation sites for eggs and fry of salmonids has long been realized. Only relatively recently has the extent (Stanford and Gaufin 1974) and importance of this special habitat for stream invertebrates been fully appreciated in North America. Many species utilize the hyporheic zone, especially as early instars, and this habitat provides a refuge for organisms during adverse conditions.

The direct influence of the terrestrial environment decreases downstream as the canopy opens and *in situ* primary production becomes more important. In regions of deciduous forests especially (but not exclusively), leaf litter and other coarse particulate organic matter (CPOM) comprises the primary energy source for headwater streams. Much of this coarse detritus is changed to fine particulate organic matter (FPOM) which is transported downstream.

The greatest amount of light reaches the stream bottom in middle reaches; upper reaches are shaded; lower reaches are often highly turbid. Mosses and shade-tolerant algae are the major plants in headwater streams. Aquatic angiosperms and periphytic algae are best developed in middle reaches. In the turbid, slow-flowing portions of large rivers the major producers are the phytoplankton. In upper reaches, organisms which are carried by the current are benthic forms temporarily drifting rather than permanently planktonic species.

The CPOM, and associated microorganisms, are eaten by a variety of shredders. The feeding activities of these detritivorous invertebrates change the CPOM into FPOM which is fed upon by other invertebrates, the collectors. Another functional category of invertebrates, he grazers, feed on algae (and associated ine detritus) growing on rocks and other suraces. All of these invertebrates are potenial food for fishes and invertebrate predators.

Downstream, organic matter of terrestrial rigin is of lesser importance in the energy udget of the stream, and FPOM imported from pstream assumes a greater role. Whereas hredders feeding on CPOM are abundant in headater reaches, they decrease in importance downtream, concomitant with an increase in collecors feeding on FPOM. The grazers reach greatst abundance in middle reaches were periphyton s well developed.

As expected, the fish fauna changes downstream as cold water species are replaced by cool water species and eventually by warm water fishes. Invertivores are predominant in the headwaters; in middle reaches piscivorous fishes occur as well; bottom feeders and planktivorous species become important in the largest rivers (Cummins 1979).

Some of the preceding generalizations regarding natural stream ecosystems were developed by stream biologists working in the temperate deciduous forest and may not always apply to other regions such as the western U.S. (Minshall 1978). It is, however, essential to have a basic understanding of stream ecology concepts to understand the effects of stream regulation on the aquatic biota. Damming a headwater stream has quite different biological implications than damming a large river.

GENERAL EFFECTS OF DAMS

When a dam is placed across a flowing water system, not only is the inundated portion behind the dam changed but the downstream reach will never be the same as the previously unregulated stream. The environmental conditions in the receiving stream (fig. 1) are a function of (1) the quality of water entering the reservoir, (2) limnological phenomena occurring within the lentic system, and (3) operational variables at the dam. The interactions of these variables largely determine (4) the ecological conditions prevailing in the tailwaters, which affect (5) biological phenomena such as productivity and diversity.

The manager has at most only two variables which he can directly and immediately control: discharge and release depth. However, control of these variables has an influence on a multitude of other factors. Although this paper is primarily concerned with effects on the receiving stream, it should be emphasized that the downstream influence often is the reverse of that on the reservoir. For example, releasing deep water from the dam to create a cold water stream fishery will increase the heat storage capacity in the reservoir.

Although numerous operational schemes are possible, limitations of space necessitate generalization. The discharge regime depends, of course, upon the purpose of the reservoir (Ward 1976a). If water is diverted from the reservoir, a lesser total flow will result in the receiving stream. If, however, water abstracted elsewhere is added to the system, the resulting discharge will be greater than the historical flow. A dampened flow regime (reduced maximum, increased minimum) results from

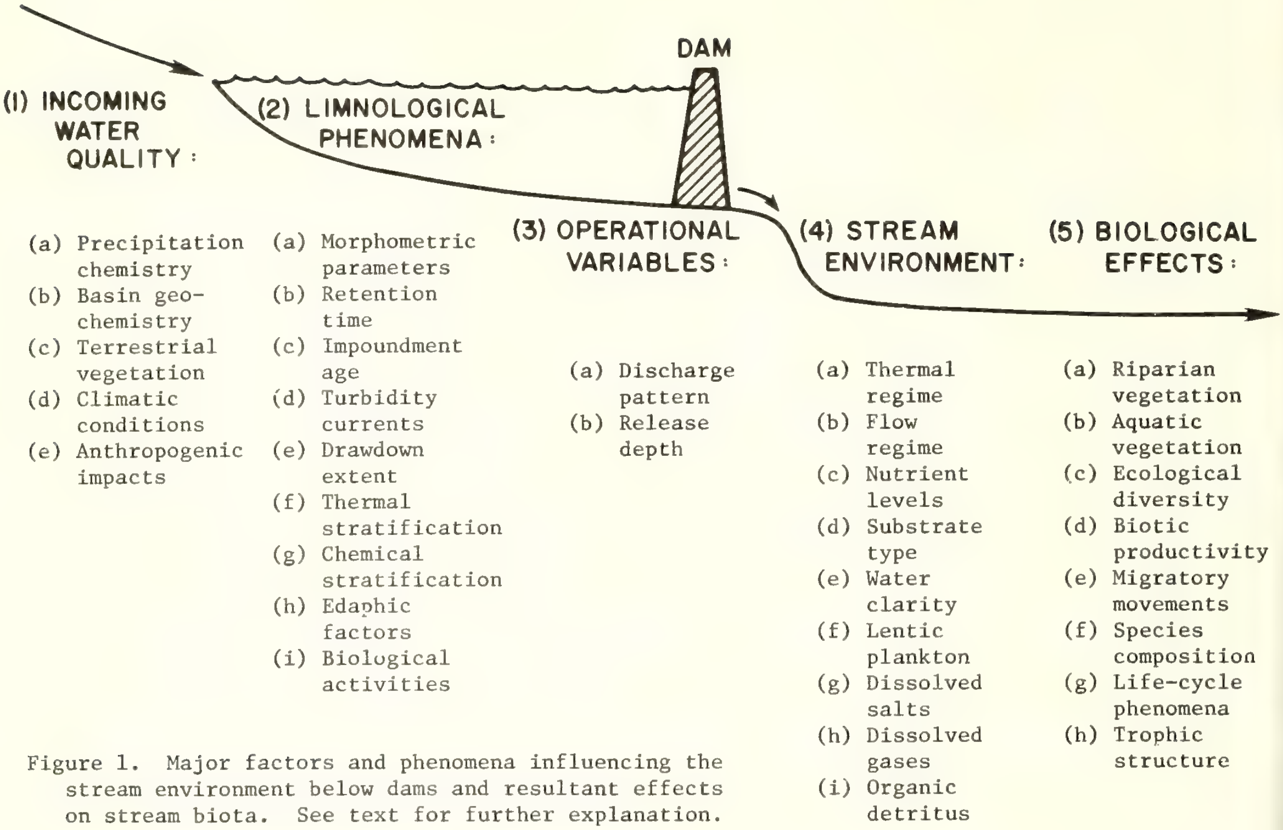

Figure 1. Major factors and phenomena influencing the stream environment below dams and resultant effects on stream biota. See text for further explanation.

certain operational schemes, whereas hydroelectric generation creates short-term flow fluctuation. The receiving stream responds hydrodynamically to all of these deviations from the natural flow regime with effects on channel morphometry, substrate and ultimately, stream biota.

For a given discharge pattern, the release depth largely determines the extent to which the thermal regime of the receiving stream will be modified. If water is released from or near the surface of the reservoir, the thermal regime will be similar to natural lake outflows. Water released near the bottom of a reservoir which thermally stratifies will produce temperatures which are cooler in summer and warmer in winter than unregulated streams. The seasonal constancy will be accompanied by diel thermal constancy, and the seasonal maximum may be delayed (Ward 1976b). Dams built with more than one release depth allow greater control of tailwater temperatures; multilevel outlet structures theoretically allow complete control of the thermal regime of the receiving stream.

The depth from which water is released also affects nutrient and salinity levels, concentrations of dissolved gases, and the amount and type of lentic plankton discharged into the tailwaters.

POTENTIAL PROBLEMS

A variety of problems may arise when a dam is placed on a previously unregulated stream. An understanding of the ecological bases of these potential problems allows greater protection of receiving stream biota utilizing the ameliorative measures possible within the strictures of the purposes and design of the project. Knowledge of stream biology also provides opportunity to modify project design based upon predicted outcomes.

Water Temperature

Daily thermal fluctuations of 6°C commonly occur in natural streams (Hynes 1970), although greater thermal constancy characterizes headwaters (due to shading and groundwater inflow) and large rivers (due to heat capacity). Receiving stream biota may suffer thermal shock if the water temperature changes too rapidly. Rapidly shifting the release depth from the epilimnion to the hypolimnion or vice versa may have disastrous consequences for the stream fauna. During the summer, the receiving stream temperature may rapidly approach atmospheric conditions during low flow periods below hydroelectric dams. During power generation, which may occur two or three times daily, discharge water may be 6-8°C lower (Pfitzer 1967).

If the penstock intake is at a depth which results in the discharge of cold water in spring and early summer only, the receiving stream will be unsuitable for either a trout or warm-water fishery. Large, shallow reservoirs may act as heat traps which raise downstream summer temperatures, thus endangering cold-water fisheries (Fraley 1979).

The majority of lotic macroinvertebrates in the temperate zone depend upon natural thermal variations to break diapause, stimulate emergence, and to cue other life cycle phenomena. The interaction of sublethal thermal factors responsible for selective elimination of macroinvertebrates in regulated streams have been reviewed elsewhere (Ward 1976b, Ward and Stanford 1979). Dams constructed to allow water to be drawn from a varying combination of reservoir depths would enable simulation of the natural daily and seasonal thermal patterns characterizing a given stream reach.

Sedimentation

Sedimentation in regulated streams may result from (1) dam construction activities, (2) elimination of the flushing action of occasional periods of high discharge, (3) reduced flow due to diversion, or (4) a combination of these factors. In addition to direct effects on biota, such as clogging respiratory surfaces and covering aquatic plants, sedimentation decreases substrate heterogeneity, and reduces or eliminates the hyporheic zone by filling interstices with silt.

Reduced flows following closure of Granby Dam on the Colorado River were insufficient to remove silt deposited during construction activities. Ameliorative measures consisting of large flow pulses over a four-day period in April were successful in removing large amounts of silt, especially from riffles (Eustis and Hillen 1954). By releasing the same total amount of water, but in a pattern simulating the natural flow regime, a more natural receiving stream environment may be maintained.

Oxygen Deficits

Natural streams tend to be saturated with oxygen, thus the majority of stream organisms have not evolved mechanisms to cope with lowered oxygen content. This is especially true of sport fishes such as salmonids, and species of macroinvertebrates which are important items in the diet of these fishes.

Deleterious effects on regulated stream biota have been attributed to decreased oxygen content (e.g. Pfitzer 1967, Ruggles and Watt 1975). Reduced substances, such as hydrogen sulfide, which are directly toxic to aquatic biota may be associated with anaerobic conditions in the reservoir. Problems of low oxygen levels normally occur only if water is discharged from the hypolimnion of eutrophic reservoirs during the period of stratification. Oxygen is rapidly restored downstream if turbulent conditions prevail. Air drafts installed in release valves will normally alleviate oxygen deficits which may otherwise occur in the receiving stream.

Gas Supersaturation

The causes of gas supersaturation and effects on fishes and invertebrates have been recently reviewed (Weitkamp and Katz 1977). Water falling from high dams, mixing with air which is subsequently dissolved under the hydrostatic pressures in deep-plunge basins, can result in supersaturation levels which cause gas bubble disease in aquatic organisms. This problem has been especially severe in the Snake and Columbia River systems.

Spillway deflectors offer promise as a means of reducing supersaturation levels. These devices direct the spilled flow along the surface of the tailrace rather than allowing the water to be carried deep into the plunge basin. In addition, spillway deflectors do not decrease survival of juvenile salmonids passing over them.

Migratory Movements

Dams present several additional problems for anadromous fishes: Adults are blocked in their passage to upstream spawning areas; if not completely blocked, reservoirs increase the time necessary to reach upstream spawning grounds (which may be inundated by an impoundment); regulated discharge may not provide the stimuli to appropriately cue migratory movements; downstream migrating juveniles may suffer disproportionate losses when passing over or through dams; predators may take heavy tolls on adults and juveniles concentrated below dams; reservoirs increase the time of passage of downstream migrating juveniles; and migrants may be blocked by stratified reservoirs which have surface waters which are too warm and deeper waters which are deficient in oxygen.

While various methods, such as screening turbine intakes, constructing fish ladders, and trucking adults and juveniles around dams have been utilized, present technology may not always be sufficient to preserve the anadromous upstream fishery (Mundie 1979). Impoundments also interfere with the downstream drift of benthic stream organisms and their compensatory upstream migrations (i.e. the colonization cycle of Müller 1954). The phenomenon of drift (benthic organisms temporarily being carried downstream by the current) is a functional attribute of lotic systems (Waters 1972), which acts as a dispersal mechanism for stream benthos. Blockage of these movements by a dam may be partly responsible for the altered community structure below dams.

Community Structure

The nonmigratory fish faunas of tailwaters generally exhibit reduced species diversity compared to unregulated streams. Effects are least dramatic in northern climes where cold-water fishes are indigenous. In more southern regions the entire native fish fauna may be replaced by exotic species such as rainbow trout if discharge is from the hypolimnion. Native riverine fishes in the southwestern U.S., such as the species endemic to the Colorado River Basin (Holden 1979), have quite different ecological requirements and behavioral attributes than salmonids. Damming rivers in these arid regions may create habitat conditions suitable for cold-water recreational fisheries at the expense of the native species.

Whereas the effects of stream regulation on macroinvertebrate standing crop are variable, species diversity is nearly always reduced and the taxonomic composition of tailwater invertebrates is grealy modified compared to natural streams (Ward 1976c).

Increased flow constancy favors species able to tolerate the modified thermal conditions, but which are unable to maintain populations in unregulated high-gradient streams (e.g. amphipods, snails, the mayfly *Tricorythodes minutus*).

Rapid flow fluctuations eliminate accumulations of CPOM (leaf litter) and therefore most shredder species. Hyporheic forms may be favored providing suitable silt-free interstices are available.

Tailwaters below surface-release dams are often dominated by collectors due to the release of plankton produced in the reservoir. Filter-feeding caddisflies (Trichoptera) and black flies (Simuliidae) may develop high densities.

Entire groups (e.g. stoneflies, heptageniid mayflies) may be rare or completely absent from the receiving stream. The modified thermal regime below dams is a major factor responsible for species elimination below dams.

Productivity

As a broad generalization, it may be stated that productivity, at least in the short term, will be enhanced by increased flow constancy and decreased by flow fluctuation. Enhanced seasona flow constancy, even if associated with daily flow fluctuations, generally enhances benthic productivity. There are many exceptions and other factors such as pollution or thermal shock may be the major determinant of biotic productio in the receiving stream. In addition, if there is a higher level of production, it often result from enhancement of species representing but a small fraction of the inhabitants of a natural stream system.

Factors which generally increase standing biomass in regulated streams include (1) decreased bank and bed erosion, (2) absence of surface and anchor ice, (3) increased nutrients, (4) decreased turbidity, and (5) inputs of lentic plankton from the reservoir. Some of these factors act directly on a given faunal component others such as the first four listed above act indirectly by enhancing algal growth, for example. The first three factors result from increased flow constancy; the fourth and fifth are general characteristics of streams below dams. In certain tailwaters, inputs of forage fishes from reservoir populations have accounted for rapid growth of trout.

Eutrophication, defined as excessive nutrient levels, and concomitant increases in aquatic vegetation, may be a problem in certain tailwaters. Stream conditions are, of course, a function of the trophic state of the reservoir, which is influenced by a variety of factors in the drainage basin as well as limnological phenomena in the reservoir (fig. 1). Reservoirs are typically highly productive the first few years after impoundment, especially if nutrient-rich agricultural or grazing lands are inundated. Outflowing waters may have greater or lesser concentrations of a given nutrient than waters entering the reservoir.

Both operational variables, discharge pattern and release depth, may be utilized by the manager to influence tailwater productivity. Nutrients and other dissolved substances increase in concentration with reservoir depth. Deep release, therefore, will tend to enhance receiving stream productivity, whereas lower nutrient surface waters would be more appropriate for eutrophic tailwaters. Enhancing flow constancy, at least on an annual basis (or decreasing the rate of flow fluctuation) would be the appropriate managerial strategy to increase tailwater productivity, whereas simulated spring runoff and spates would reduce the buildup of algal mats.

CONCLUSIONS

A myriad of altered conditions may adversely influence, or at least seriously modify, he biota in regulated streams. Some conditions uch as gas supersaturation, rapid flow fluc- uation, or thermal shock are obvious to biol- gist and non-biologist alike. Other changes f great significance to the biota, such as ncreased constancy of the thermal and flow egime, may not be immediately recognized as roblems.

Temperate stream organisms have evolved n response to a highly heterogeneous environ- ent. The considerable temporal variations in actors such as discharge, temperature and food vailability are responsible for the rich iversity of life in natural streams. A heter- geneous substrate allows a variety of species o coexist in quite different microhabitats in lose proximity. A heterogeneous trophic tructure, including a variety of sizes of etrital particles, provides a variety of food iches. The redistribution of organic detritus nd the displacement of benthic algae by natu- al floods function as important reset mecha- isms in stream ecosystems (Cummins 1979).

Since temperature and flow regimes are so nportant in determining the biotic and abiotic onditions of the receiving stream, the opera- ion of those variables at a dam site has great cological implications, which should be major onsiderations in reservoir construction and peration.

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Use of Dredged Material Disposal in Mitigation[1]

L. Jean Hunt[2]

Abstract.--Planned disposal of dredged material and subsequent development of upland and wetland habitat is a potential means of mitigating habitat losses due to water resources projects. The background, potential, constraints, and suggestions for use of this concept are presented.

BACKGROUND

When sediments dredged from navigation channels and harbors are considered a resource and not waste material, it is often possible to use them productively to develop and aid in management of habitat. This was a premise tested during the 5-year Dredged Material Research Program (DMRP), conducted between 1973 and 1978 by the Corps of Engineers at the Waterways Experiment Station in Vicksburg, Mississippi. Overall objectives of the DMRP were to provide information on the environmental impact of dredging and dredged material disposal operations and to develop disposal alternatives, including consideration of dredged material as a manageable resource. Four major projects within the DMRP dealt with environmental impacts and criteria development, disposal operations, habitat development, and productive uses.

The Habitat Development Project tested the feasibility of using dredged material as a substrate for the establishment of vegetation and wildlife habitat. Since the DMRP was national in scope, a variety of test conditions was sought to provide data that could be extrapolated for use over large areas. Literature, laboratory, and field studies were conducted. Literature reviews were written to consolidate existing information such as the state-of-the-art of marsh plant establishment techniques (Wentz et al. 1974) and selection of plants for terrestrial wildlife habitat development (Coastal Zone Resources Division 1978). Laboratory studies were conducted largely on various aspects of marsh plant growth such as heavy metal uptake (Lee et al. 1978) and the relationship of plants to differing dredged material characteristics (Barko et al. 1977).

Field research included discrete topics such as productivity of marsh plants (Reimold and Linthurst 1977), widespread surveys such as the use of dredged material islands by nesting waterbirds, and field experimentation on establishing marsh and upland habitat.

The latter two efforts have the greatest relevance to dredged material disposal for mitigation purposes. The goal of the waterbird survey was to determine the information and principles necessary for developing and managing dredged material islands for colonial nesting bird species. Seven regions of the United States were studied for waterbird use and vegetation patterns as tabulated below.

LOCATION AND CITATIONS FOR DREDGED MATERIAL ISLAND AND WATERBIRD SURVEY

LOCATION OF STUDY AREA	REPORT CITATION
New Jersey coast from Pt. Pleasant to Cape May Inlet	Buckley and McCaffrey (1978)
North Carolina coast from Albemarle Sound to mid Long Bay	Parnell et al. (1978)
Florida east and west coasts (5 disjunct study areas)	Schrieber and Schrieber (1978), Lewis and Lewis (1978)
Texas coast including Galveston Bay system and the Laguna Madre	Chaney et al. (1978)
Oregon and Washington (5 coastal bays and harbors)	Peters et al. (1978)
U. S. Great Lakes shoreline and islands	Scharf et al. (1978)
Upper Mississippi River from Alton, IL to St. Paul, MN	Thompson and Landin (1978)

Each regional study was reported and a synthesis of results was prepared (Soots and Landin 1978).

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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Major experimental field tests were constructed in seven locations to test certain engineering and vegetation establishment techniques and principles. The sites are briefly characterized in Table 1. A summary report describing planning, construction, and monitoring activities at each field site was prepared. Field site data, other relevant DMRP information, and outside sources were used to prepare synthesis reports on marsh development (Environmental Laboratory 1978) and upland habitat development (Hunt et al. 1978a).

Table 1 --Characterization of Habitat Development Field Sites

Site Name	Location	Type of Habitat Development	Substrate	Salinity	Summary Report Citation
Miller Sands	Lower Columbia River, Astoria, Oregon	Marsh and upland	Sand	Fresh	Clairain et al (1978)
Salt Pond 3	South San Francisco Bay, California	Marsh	Clay	Saline	Morris et al (1978)
Bolivar Peninsula	Galveston Bay, Texas	Marsh and upland	Sand	Saline	Allen et al (1978)
Drake Wilson Island	Apalachicola Bay, Florida	Marsh	Silt fill sand dike	Saline to brackish	Kruczynski et al (1978)
Buttermilk Sound	Atlantic Intracoastal Waterway, Brunswick, Georgia	Marsh	Sand	Fresh to brackish	Cole (1978)
Windmill Point	James River, Chester, Virginia	Marsh	Silt fill sand dike	Fresh	Lunz et al (1978)
Nott Island	Connecticut River, Essex, Connecticut	Upland	Sand and silty sand	Fresh with salt wedge	Hunt et al (1978b)

In addition to the three synthesis reports mentioned above, two additional reports were prepared on aspects of habitat development. Smith (1978) provides an introduction to the subject and a listing of the DMRP reports pertinent to habitat development. Lunz et al. (1978a) discusses ecological considerations such as management objectives, application of ecological principles, and habitat displacement.

WHAT WAS LEARNED

As a result of the DMRP and other recent efforts, the ability to dispose of dredged material in a biologically productive manner was demonstrated. The engineering characteristics and behavior of dredged and disposed sediments can be predicted and determined. If the sediments are contaminated, a decision can be made on their safety for use and accessibility of contaminants to the system. Information on site selection criteria exists to locate disposal areas for habitat development so as to enhance project success. Techniques for site construction are known. Criteria for plant species and propagule type selection have been developed, related to conditions, constraints, and goals of the project. It is also known when a site should not be planted, either because of a management objective or because natural plant invasion will be adequate. The changes that occur on a site over time can be predicted. Potential adverse impacts can be recognized and alleviated.

THE POTENTIAL

A number of features of the dredging and disposal operation make it amenable to habitat development and mitigation activities. Dredged material is a readily available resource in many locations, especially near coasts, harbors, navigable waterways, or river mouths. This, of course, is the area of most concern to the mitigation issue (Rappoport 1979). The Corps of Engineers dredges approximately 305,000,000 cubic metres of sediments annually (Boyd et al. 1972); private and industrial concerns do additional dredging.

Dredging is a combination of construction and maintenance sediment removal. Dredging for construction, as in the establishment of a deeper channel, results in one-time disposal. Maintenance dredging occurs in a cycle that can range from annually to once every ten or more years. The dredging frequency, volume of sediments, and type of material can be generally predicted. Because of its recurrence, maintenance material can be considered a management tool.

Sediments removed from a waterway and dewatered can be analyzed and used as a soil (Bartos 1977). They may be subjected to standard soil properties tests such as grain-size analysis, shear strength, pH, and fertility. They may then be treated as a soil, e.g. used in construction or fertilized or limed to improve plant growth.

Four forms of habitat can be established on dredged material: marsh, aquatic, upland, and island (specialized upland). Within each of these types are subtypes, e.g. high or low marsh, early successional or advanced island vegetation. A number of habitat choices are therefore available for consideration. Limits on the choices will likely be due to constraints of site selection, funding, or factors other than the dredged material itself.

A substrate of dredged material can produce a valuable habitat and contribute to the productivity of the area. The Windmill Point field site in the James River, Virginia, was constructed in early 1975 by placement of a sand retaining dike and silt fill. Within six months a thick cover of invading fresh water marsh species had established, upland vegetation was growing on the dike, tidal channels had formed, and wildlife and fish use of the site was occurring. Because of its diversity, the site became a source of cover and food for a large variety of species, and was more productive than the pre-existing river bottom (Lunz et al. 1978b).

Another factor contributing to the potential of habitat development is the appeal to the public. When a site is built and becomes a good spot for hunting, fishing, or birding, or fir just looks green and attractive, the site and the concept behind it gain acceptance.

Habitat development is frequently a low cost disposal and management option. If no structures for retention or protection of the sediments are required, and if the sediments are placed to maximize plant invasion so no funds are needed for propagation, the costs will be basically limited to those of the dredging operation itself. Likewise, placement of material to retard plant succession is an inexpensive and non labor-intensive means of vegetation control.

THE CONSTRAINTS

Capabilities of the dredging equipment will affect and possibly restrict habitat development options, primarily because the distance or height that material can be moved may be limited. Hydraulic dredging is most often associated with habitat work; if a booster pump is needed to move the material to a site, the cost increases.

Costs also rise with addition of construction requirements (e.g. retaining dikes), complexity of the dredging and disposal process (e.g. moving the disposal pipe to achieve a desired topography), and modifications to the dredged material once in place (e.g. grading or planting).

Ecological constraints include potential adverse impacts. Material contaminated with industrial or agricultural wastes should be examined for possible mobility of the contaminants in sediments and plants. Deposition of material in water may affect circulation patterns, resulting in changes of salinity, sedimentation, or erosion rates. The question of relative habitat values arises when deposition will cause replacement of an existing habitat type.

Location of a disposal site is a problem in many dredging projects. For habitat development, sites may be unsuitable because of physical, environmental, or sociopolitical conditions. Examples of restrictions on site location include excessive wave or wind energies, existence of wetlands that are to be protected, and zoning ordinances.

USE OF DREDGED MATERIAL IN MITIGATION

There are four means of developing or modifying habitat with dredged material to serve the purpose of mitigation. They are to create new land, replenish a substrate, restore bare ground, and manage a plant community.

If dredged material is placed on a submerged substrate and raised to an emergent elevation, it is considered new land. New land may result by building islands or by extending a projection of existing land. Before this option is pursued, it should be examined for potential impacts related to sedimentation, erosion, salinity ranges, and circulation patterns. The water bottom to be covered must be evaluated and a decision made on the relative value of the existing and potential habitats. Another concern is ownership of existing fast land; state laws vary on who becomes the owner of new land.

Because of the potential for adverse hydrologic impacts and difficulty of prediction, creation of new land should be considered only if no other options are suitable or if a clear need exists for new land. An example of the latter case might be a need to provide nesting or resting habitat for waterbirds in an area where such habitat is limited.

Wetland substrates subjected to subsidence or erosion can benefit from a deposit of dredged material to replenish what has been lost. The critical factor is maintaining an elevation of the new fill that will be inundated At upland sites where dredged material has been removed for other uses such as industrial fill, new sediments may be placed and used as a substrate for habitat development.

Bare ground can be restored if a deposit of material is placed to a depth sufficient to kill the vegetation present. With no propagation efforts it will remain bare for a varying length of time determined by the soil properties and their favorableness to plant growth, elevation of the site, the season of year and climate, number of plant species available for invasion, and their accessibility to the site. Some of the high, sandy dredged material islands near Corpus Christi, Texas, take 30 years to develop vegetative cover, while those near Galveston are in a wetter climate and are vegetated within 3-5 years. The habitat development field sites in Georgia and Oregon were both sand substrates and intertidal but showed a great difference in invasion and colonization rates.

Bare substrates are particularly valuable in dredged material island management when the target species is one such as the least or royal tern which requires a lack of vegetation at the nest site. For other management goals, it may be desirable to plant the site with selected species. First consideration on a new substrate should be given to species able to colonize, compete, and become established.

Regular deposition of material can be used in the same fashion as fire or herbicides to manage a given plant community. The greatest potential offered is likely to be the prevention of shrubs and trees from invading grasslands. A danger, however, is that after several depositions, the elevation of the site may become too high to allow plant roots to reach the water table.

EXAMPLES OF USE

Planned disposal and habitat development lends itself to either featured species or species richness management, as defined by Black and Thomas (1978). Waterfowl management is a common goal for water-related projects. A well-planned habitat including feeding, nesting, and loafing sites and escape cover can increase waterfowl populations in an area. This development might take the shape of nesting islands in a body of water, marshes on the edge, and grazing pastures on adjacent upland.

Rare or endangered species may be featured, even though as a rule they are not associated with a disturbed and unstable environment. An outstanding possibility is management for colonial waterbirds by providing nesting habitat to replace that destroyed by land development and other human activites. This has the potential of positively impacting a large percentage of the population. For example, ten species of plovers, terns, and herons are in a "Special Concern" category in North Carolina (Cooper et al. 1977). All have been recorded as nesting on dredged material, and could be the focus of an intensive management program (Soots and Landin 1978).

Species richness management involves managing for diversity and quality of the habitat. Dredged material can be effectively used to add diversity to an area by establishing an upland habitat in the midst of an expanse of wetlands, a wetland in an area lacking wetlands, or a different subtype of habitat such as grassy clearings within a stand of trees. Quality of a habitat can be enhanced by manipulation of vegetation to improve food and cover for the maximum number of species. Typical management techniques such as plowing and fertilization may be used on dredged material, or plant species particularly beneficial to a variety of wildlife may be planted. Coastal Zone Resources Division (1978), Hunt et al. (1978a), and Landin (1978) give life histories and propagation requirements of plant species on dredged material.

Intensive management of project lands is one means of overcoming habitat losses due to the project; dredged material disposal can be incorporated into such a management scheme. Examples of intensive management are construction and maintenance of nesting islands and disposal to create movement corridors and food patches.

RECOMMENDATIONS

Habitat development on a substrate of dredged material is feasible and has potential for improving the biological quality of an area. Recommendations for implementing this concept include the following:

(1) Full coordination of all agencies involved in the project should be maintained during the planning process. This is necessary to incorporate all viewpoints and to address any questions or doubts that arise.

(2) Strong interdisciplinary interaction is required for a successful project. The talents of several types of engineers and physical, biological, and social scientists may be applicable.

(3) All types of habitat development should initially be considered. There is no inherent characteristic of any one option that technically removes it from consideration before examination in light of a particular site or situation.

(4) Monitoring the site's development is necessary (a) to assure that it proceeds as planned, both during and immediately following construction and during the life of the project; and (b) to perform any maintenance or management activities necessary for a successful project.

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The Kissimmee River Channelization: A Preliminary Evaluation of Fish and Wildlife Mitigation Measures[1]

Frank Montalbano, III, Karen J. Foote, Michael W. Olinde, Larry S. Perrin[2]

Abstract.--The Kissimmee River channelization resulted in extensive elimination of wetlands and riverine habitat despite implementation of construction measures planned to mitigate losses. Land management practices facilitated by channelization and incidental to operation of the flood control system had a detrimental impact on the effectiveness of fish and wildlife mitigation measures incorporated during project construction.

INTRODUCTION

The waters of the Kissimmee Valley rise near Orlando, Florida (Figure 1). Historically, flow was through a system of marshes and sloughs between numerous lakes of the upper Kissimmee Valley to Lake Kissimmee. The Kissimmee River carried waters from Lake Kissimmee through a meandering channel and a mile-wide marsh floodplain (Florida Dep. of Adm. 1975, Goodrick and Milleson 1974) approximately ninety river miles to Lake Okeechobee.

Water levels in the basin fluctuated considerably in response both to seasonal rainfall and periods of abnormally high rainfall and drought (Wegener and Williams 1974, Burns 1976). Extremes in natural fluctuation were key elements in the system's productivity, resulting in major substrate improvement (Wegener and Williams 1974), germination of diverse aquatic and wetland plants (Goodrick and Milleson 1974; Wegener and Williams 1974), and concentration of forage fish for utilization by game fish and birds (Burns 1976).

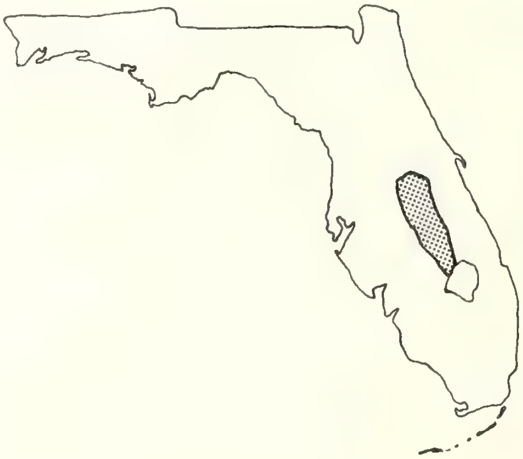

Figure 1. Kissimmee Basin, Florida.

The extensive marsh system supported an abundance of fish and wildlife (Florida Dep. of Adm. 1975), including waterfowl, wading birds, alligators, and game mammals (Dineen *et al.* 1974). Bellrose (1968) described a significant waterfowl migration corridor extending through the Kissimmee Valley, and Chamberlain (1960) reported that waterfowl use of the extensive marsh prairie transition zone along the river was considerable. Fish and wildlife resources of the area traditionally afforded quality recreational opportunities for sportsmen and nature enthusiasts from throughout the United States.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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Drainage of the Kissimmee Valley began in the 1880's with the dredging of a series of canals between the principal lakes in the upper basin. The purpose of this activity was to permanently lower water levels in the upper valley (Craighead 1971; Florida Dep. of Adm. 1975). Congressional authorization for construction of the flood protection system was granted in 1954 (Dineen et al. 1974). In the 1960's the U. S. Army Corps of Engineers (Corps) constructed the authorized public works project to regulate water levels in the upper chain of lakes (Florida Dep. of Adm. 1975). In 1971 excavation of canal C-38 and the system of water control structures (S-65, S-65A through S-65E) along the route of the Kissimmee River between Lake Kissimmee and Lake Okeechobee was completed (Goodrick and Milleson 1974; Dineen, et al. 1974).

Recognizing that the channelization of the river had resulted in deterioration in specific values pertinent to quality of life, including fish and wildlife habitat, populations, and associated recreational opportunities, the Florida Legislature took action in 1976 to develop measures to alleviate these problems. In 1977 the Legislature called upon the U. S. Congress to authorize the Corps to determine if the system of works in the Valley should be modified with respect to water quality, flood control, recreation, navigation, loss of fish and wildlife resources and other environmental amenities. The Ninety-fifth Congress complied with this request, and in 1978 the Corps initiated the ongoing Kissimmee River Survey Review.

In an effort to understand and document deterioration of fish and wildlife habitat, populations, and associated recreational opportunities which occurred following completion of C-38, the Florida Game and Fresh Water Fish Commission (GFC) undertook an examination and evaluation of fish and wildlife mitigation measures incorporated during project construction. Preliminary results are presented in an effort to foster understanding of factors which influenced the effectiveness of mitigation. As used herein, mitigation refers to measures designed to moderate or lessen the impact of project construction on fish and wildlife resources. Mitigation should not be confused with compensation, which implies substitution of populations or habitat of equal value.

We gratefully acknowledge the assistance provided by Wildlife Biologist S. B. Fickett, GFC, who provided aerial survey data for the early 1970's and L. Ager, G. Atmar, J. Carroll, J. W. Dineen, S. Gatewood, B. Hartman, and J. Johnston who reviewed and provided helpful suggestions with the manuscript.

MATERIALS AND METHODS

Selected fish and wildlife mitigation measures incorporated during construction of C-38 were identified based on information provided in U.S. Army Engineering District General Design Memoranda and Detailed Design Memoranda, pre-construction recommendations of the U.S. Fish and Wildlife Service (FWS) and GFC and pertinent correspondence. Mitigation measures identified are:

1. Pool marshes - Provision for permanent wetlands above each of five water control structures along the canal (U.S. Army Engineers 1958, Garland[3]).

2. Impounded wetlands - Construction and/or incorporation into the system of works of a series of impounded wetlands and water control structures north of S-65B for waterfowl habitat management. (Wallace,[4] Koperski[5])

3. Spoil placement - Minor realignment of spoil deposition in a manner to reduce destruction of critical habitats (U.S. Army Engineers 1958, 1962, 1963, H.E. Wallace[6]).

4. Fish breeding canals - Construction of "fish breeding canals" to provide suitable spawning areas adjacent to C-38. (U.S. Army Engineers, 1958, 1962, 1963).

5. River access - Deposition of spoil in a manner which would maintain access between C-38 and remnants of oxbows and channels of the river.

Data were compiled from various pre- and post-channelization studies of fish and wildlife populations and associated recreational use in an effort to document and support assessment of the effectiveness of mitigation measures.

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[3] Pers. comm., J.L. Garland, U.S. Army Corps of Engineers, 1978.

[4] Pers. comm., H.E. Wallace, Florida Game and Fresh Water Fish Comm., to District Engineer, U.S. Army Corps of Engineers, Oct. 25, 1966.

[5] Pers. comm., J.J. Koperski, U.S. Army Corps of Engineers, to Florida Game and Fresh Water Fish Comm., Nov. 1, 1966.

[6] Pers. comm., H.E. Wallace, Florida Game and Fresh Water Fish Comm., to Central and Southern Florida Flood Control District, Sept. 17, 1965.

Habitat Quantity

Mitigation of Wetlands and Riverine Habitat Loss. Total wetland area prior to and following channelization as compiled by Pruitt and Gatewood (1976) were reviewed to assess the effectiveness of pool marshes, impounded wetlands, and spoil placement in mitigating loss of wetlands habitat in the floodplain. Maintenance of access between C-38 and remnants of oxbows and channels of the river (river access) were examined. Total miles of active river channel in the system prior to channelization and remnant river channel and old oxbows accessible to C-38 following channelization were determined from 1953 U.S. Geological Survey (USGS) Topographic Maps and 1972 USGS Photo Revised Topographic Maps, respectively. Joe Johnston[7] provided documentation of the total miles of fish breeding canals identifiable on 1974 aerial photographs of the floodplain.

Habitat Quality

Mitigation of Waterfowl Losses. Changes in duck use were used to assess the quality of waterfowl habitat maintained through implementation and construction of pool marshes, impounded wetlands, and spoil placement (mitigation measures 1, 2 and 3). Annual duck use as determined from aerial surveys conducted before and after completion of channelization are presented and compared using the Student's "t" test.

Mitigation of Fish Losses. Species composition of fish samples collected in the Kissimmee River system prior to channelization is reported. Sampling was conducted with rotenone, wire traps, otter trawl, hoop nets and gill nets (GFC 1957). Post-channelization sample results are presented to assess species composition in various habitat types and to evaluate the effectiveness of pool marshes, fish breeding canals, and river access in maintaining fish species diversity. Sampling was conducted in the C-38 canal, remnants of the river channel and associated marshes with rotenone and tub samples (Ager 1971, Milleson 1976, Milleson[8]) with trammel nets and electroshocker,[9] and with minnow seine, trawl and gill net[10]. Sampling in the fish breeding canals was conducted with rotenone (FWS,[11] Ager 1971).

Results of a stratified roving creel survey with non-uniform probabilities developed by the Southeastern Fish and Game Statistics Project, Statistics Department, North Carolina State University, and conducted during the period September 1978 through February 1979 are evaluated to assess the effectiveness of pool marshes, spoil placement, fish breeding canals, and river access in maintaining sport fishery values in the Kissimmee River system. Preliminary estimates with proportional standard errors less than or equal to 0.30 are presented and compared with estimates of fishing pressure and success obtained in the Kissimmee River prior to channelization from angler interviews and other unspecified methods (FWS 1959).

RESULTS AND DISCUSSION

Habitat Quantity

Mitigation of Wetlands and Riverine Habitat Loss. Data developed by Pruitt and Gatewood (1976) indicate that 16,443 ha (40,600 acres) of marshland existed in the floodplain in 1954. In 1974, 3,580 ha (8,840 acres) remained. Prior to channelization there were approximately 216 km (134 mi) of active braided river channel in the floodplain. The river access mitigation measure maintained access to 54 percent of this channel, a total of approximately 116 km (72 mi) (does not include C-38). Additional mitigation of losses persists in the form of approximately 42 km (26 mi) of fish breeding canals and 71 km (44 mi) of spoil borrow ditches[7]

The loss of floodplain wetlands which resulted from channelization was substantial. Virtually all remaining wetlands resulted from implementation of pool marsh, impounded wetland, and spoil placement mitigation measures. Thus these measures were effective in lessening or moderating the areal extent of wetlands loss. However, the mitigation measures can hardly be viewed as compensating for the 78 percent reduction of wetland habitat which occurred. It should be noted that the actual area inundated prior to channelization varied between years with water levels. Wetlands reported by Pruitt and Gatewood (1976) reflect high water conditions.

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[7] Pers. comm., J. Johnston, U.S. Fish and Wildl. Serv., 1979.

[8] Pers. comm., J.F. Milleson, South Florida Water Management District, 1979.

[9] Pers. comm., L. Ager, Florida Game and Fresh Water Fish Comm., to J.W. Woods, Florida Game and Fresh Water Fish Comm., Oct. 5, 1970.

[10] Unpublished data, Florida Game and Fresh Water Fish Comm., 1979.

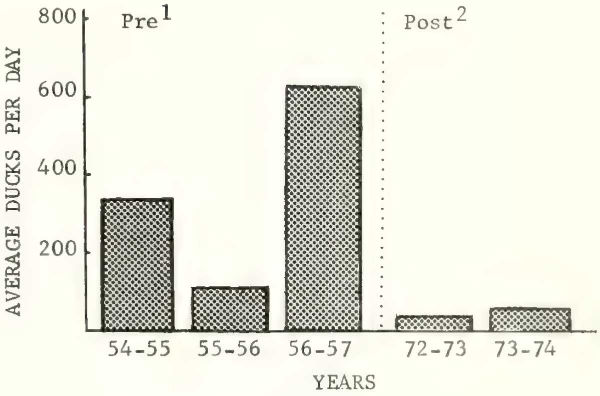
[11] Unpublished data, U.S. Fish and Wildl. Serv., 1965.

Mitigation of destruction of active river channel must be viewed similarly. The reduction from 216 km (134 mi) of braided, active river channel to 116 km (72 mi) of remnant channel represents a considerable net loss. Yet maintenance of access between the 92 km (57 mi) of C-38 canal and 116 km (72 mi) of remnant river channel certainly may moderate and lessen adverse impacts. The addition to the complex of canal and old river channel of approximatley 42 km (26 mi) of fish breeding canals may be viewed as additional mitigation of river channel loss.

Habitat Quality

Mitigation of Waterfowl Losses. Results of aerial surveys conducted prior to and following channelization are presented in Figure 2. Average ducks per day declined from 373.97 prior to channelization to 49.52 following channelization. The decline was significant at the 0.10 level ($P < 0.10$). Although differences are not significant at the 0.05 level, we believe they are nevertheless real. Variability in pre-channelization counts and small sample size contributed to the lower significance. Data suggest that substantial reduction in winter duck populations in the floodplain resulted from the combined impacts of the elimination of 78 percent of the floodplain and deterioration in habitat quality on remaining wetlands. Stabilization of water levels and certain other land management practices associated with remaining wetlands have contributed to this deterioration of habitat quality. Waterfowl habitat in the floodplain was historically associated with seasonally inundated marshes (Chamberlain 1960). Period of inundation was of primary importance in determining the composition of plant communities on such marshes in south Florida (Sincock and Powell 1957, Pesnell and Brown 1977). Goodrick and Milleson (1974) report that post-channelization stabilization of water levels has reduced the diversity of aquatic and wetlands plant species in the floodplain. This stabilization of water levels on wetlands maintained under pool marshes (mitigation measure 1) was intentionally incorporated in the Kissimmee River Project (Goodrick and Milleson 1974).

Figure 2. Aerial waterfowl survey counts for the Kissimmee River Floodplain, pre-channelization (1954-57) and post-channelization (1972-74).



[1] November thru March.

[2] November thru February.

The ability of impounded wetlands (mitigation measure 2) to sustain quality waterfowl habitat has been compromised by associated land management practices. In 1971, the Central and Southern Florida Flood Control District (FCD) requested[12] and received[13] permission to withdraw a significant portion of the impounded wetlands from planned waterfowl management to facilitate environmental studies. Under these studies, impounded wetland tracts totaling approximately 81 ha (200 acres) have been managed under a regulated hydroperiod. Periodicity of seasonal highs and lows correspond approximately to that which occurred prior to channelization, but the magnitude of fluctuation and duration of stage is reduced. Additionally, except for relatively brief reflooding reported by Milleson (1976), approximately 242 ha (600 acres) of this impoundment system has been drained to facilitate cattle grazing.[14]

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[12] Pers. comm., D.O. Morgan, Central and Southern Florida Flood Control District, to H.E. Wallace, Florida Game and Fresh Water Fish Comm., Oct. 29, 1971.

[13] Pers. comm., H.E. Wallace, Florida Game and Fresh Water Fish Comm., to D.O. Morgan, Central and Southern Florida Flood Control District, Nov. 4, 1971.

[14] Pers. comm., J.W. Dineen, South Florida Water Management District, 1979.

Remaining area resulting from impounded wetlands is included in an impoundment of approximately 600 ha (1,500 acres) constructed on the U.S. Air Force Avon Park Bombing Range (APBR). Although constructed to retain waters up to approximately the 45-foot (13.7 m) m.s.l. contour, a right-of-way easement was obtained to flood the area only to the 40-foot (12.2 m) m.s.l. contour (Contract No. DACA 17-2-67-1). Perceived conflicts with APBR grazing lease operations obstructed efforts by the GFC to raise water levels above the 40-foot (12.2 m) m.s.l. contour through 1977[15] and blockage of control structures by FCD pursuant to environmental studies previously described reduced the latitude to lower the impoundment below 40 feet m.s.l. (12.2 m). As a result, approximately 26 percent of the impoundment was permanently flooded, while remaining areas were permanently drained. During the summer of 1978, APBR initiated a program which includes seasonal reflooding of the marsh under a "multiple use" management effort. Since this program includes forage availability commitments under recently revised grazing leases,[16] the emphasis placed upon waterfowl habitat in this management program must be monitored to evaluate its impact on waterfowl habitat values.

In summary, while substantial wetland area was maintained through mitigation measures previously discussed, management strategies associated with these areas have resulted in dramatic deterioration in waterfowl habitat quality. Thus mitigation measures can not be viewed as effective in moderating adverse impacts on waterfowl habitat and populations.

Mitigation of Fish Losses. Results of fish sampling conducted in the Kissimmee River system between Lake Kissimmee and Lake Okeechobee before and after construction of C-38 are presented (Table 1). Prior to channelization, 39 fish species were collected in mainstream and shoreline habitats of the river and in associated marsh and slough systems (GFC 1957). Sampling conducted following channelization confirmed the occurrence of 32 species of fish in the Kissimmee River system (including C-38, remnants of the river channel, and associated wetlands), all of which were also collected prior to channelization. The 7 fish species which were not collected following channelization occurred infrequently in pre-channelization collections. While these species are not believed to be extirpated from the system, they may occur less frequently than before channelization. Twenty-seven species were collected within the C-38 canal and in river channel remnants. Sixteen species were collected in adjacent wetlands similar to pool marshes and impounded wetlands, including 3 species which were not collected within the C-38 canal or in remnants of the old river channel. Sampling in the fish breeding canals yielded 28 species of fish, 4 of which were not collected within the C-38 canal or in river channel remnants.

In summary, pool marshes, impounded wetlands, and fish breeding canals provided habitat for 5 species of fish which were not collected within the C-38 canal or in remnants of the old river channel maintained as a result of the river access mitigation measure. These species (Seminole killifish, sailfin molly, least killifish, brook silversides and Everglades pygmy sunfish) are associated with dense vegetation and quiet water (McLane 1955), conditions which are not typical of the C-38 canal.

Fish breeding canals have provided some measure of mitigation for the loss of fish breeding habitat due to channelization. Reproduction of centrarchids (including largemouth bass, black crappie, bluegill sunfish, redear sunfish, spotted sunfish and warmouth) was documented in fish breeding canals adjacent to the C-38 canal in April and May 1965[17] and in August and September 1970 (Ager 1971). Reproduction of channel catfish was also noted (Ager 1971).

Water hyacinth (Eichhornia crassipes) has frequently covered those fish breeding canals which have limited access to canal C-38[18,9]. Extensive mats of water lettuce (Pistia stratiotes) and encroachment of cattail (Typha sp.), bagscale (Sacciolepis striata), Scirpus cubensis, and pennywort (Hydrocotyle umbellata) into the fish breeding canals has been noted in 1978-79. Siltation of clay and fine organic matter in the fish breeding canals[9] has resulted in increasingly shallower depths with soft bottom substrates. These conditions have contributed to a decline in breeding habitat quality in many fish breeding canals.

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[15] Pers. comm., D.H. Austin, Florida Game and Fresh Water Fish Comm., 1979.

[16] Pers. comm., Paul Ebersbach, Civilian employee of the U.S. Air Force, 1979.

[17] Unpublished data, U.S. Fish and Wildl. Ser., 1965.

[18] Pers. comm., W.A. Gresh, Regional Director, U.S. Fish and Wildl. Serv., to Dist. Engineer, U.S. Army Corps of Engineers, Dec. 20, 1965.

Table 1. Fish species[1] collected in the Kissimmee River.

		Pre-channelization	Post-channelizaton		
Common name	Scientific name	Kissimmee River System[2]	C-38 Canal and River channel remnants[3]	Associated wetlands[4]	Fish breeding canal[5]
Florida gar	*Lepisosteus platyrhincus*	X	X		X
Bowfin	*Amia calva*	X	X		X
American eel	*Anguilla rostrata*	X			
Gizzard shad	*Dorosoma cepedianum*	X	X		X
Threadfin shad	*Dorosoma petenense*	X	X		
Redfin pickerel	*Esox americanus*	X			
Chain pickerel	*Esox niger*	X	X		X
Lake chubsucker	*Erimyzon sucetta*	X	X		X
Golden shiner	*Notemigonus crysoleucas*	X	X		
Pugnose minnow	*Notropis emiliae*	X			
Taillight shiner	*Notropis maculatus*	X	X		X
Coastal shiner	*Notropis petersoni*	X			
White catfish	*Ictalurus catus*	X	X		
Yellow bullhead	*Ictalurus natalis*	X	X		X
Brown bullhead	*Ictalurus nebulosus*	X	X	X	X
Channel catfish	*Ictalurus punctatus*	X	X		X
Tadpole madtom	*Noturus gyrinus*	X	X		X
Pirate perch	*Aphredoderus sayanus*	X	X	X	X
Golden topminnow	*Fundulus chrysotus*	X	X	X	X
Seminole killifish	*Fundulus seminolis*	X			X
Bluefin killifish	*Lucania goodei*	X	X	X	X
Flagfish	*Jordanella floridae*	X	X	X	X
Mosquitofish	*Gambusia affinis*	X	X	X	X
Least killifish	*Heterandria formosa*	X		X	
Sailfin molly	*Poecilia latipinna*	X		X	X
Brook silversides	*Labidesthes sicculus*	X			X
Tidewater silversides	*Menidia beryllina*	X			
Everglades pygmy sunfish	*Elassoma evergladei*	X		X	X
Bluespotted sunfish	*Enneacanthus gloriosus*	X	X	X	X
Warmouth	*Lepomis gulosus*	X	X	X	X
Bluegill sunfish	*Lepomis macrochirus*	X	X	X	X
Dollar sunfish	*Lepomis marginatus*	X[6]	X		X
Redear sunfish	*Lepomis microlophus*	X	X	X	X
Spotted sunfish	*Lepomis punctatus*	X	X	X	X
Largemouth bass	*Micropterus salmoides*	X	X	X	X
Black crappie	*Pomoxis nigromaculatus*	X	X		X
Swamp darter	*Etheostoma fusiforme*	X	X	X	X
Black banded darter[7]	*Percina nigrofasciata*	X			
Striped mullet	*Mugil cephalus*	X			

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[1] Names from American Fisheries Society 1970

[2] Florida Game and Fresh Water Fish Commission 1957

[3] Per. comm., L. Ager, GFC to J. Woods, GFC, October 5, 1970. Ager 1971, Milleson 1976, per. comm., J. Milleson, South Florida Water Management District 1979, Florida Game and Fresh Water Fish Commission, unpublished data 1978.

[4] Ager 1971, Milleson 1976

[5] U.S. Fish and Wildlife Service, unpublished data 1965, Ager 1971.

[6] Recorded as Longear sunfish

[7] Recorded as *Hadropterus*

Pre-channelization surveys conducted during the drought period of 1955-56 determined that 56 percent of the fishing effort in the Kissimmee River was for largemouth bass. The FWS corrected this estimate to 75 percent of the fishing effort for periods of "normal" water levels (FWS 1959). During the period September through November 1978, approximately 60 percent of the fishing effort was for largemouth bass, while from December 1978 through February 1979, 36 percent of the effort was for this species.

The fishing effort for black crappie was not reported for the pre-channelization period. However it was reported that under normal hydrological conditions only 25 percent of the angling effort was expended for all species other than largemouth bass (FWS 1959). Preliminary results of the post-channelization creel survey of canal C-38 and river channel remnants indicated 14 percent and 33 percent of the fishing effort was expended for black crappie from September through November 1978, and from December 1978 through February 1979, respectively.

In the 1955-56 period, the estimated largemouth bass success rate (catch per hour of fishing specifically for largemouth bass) in the middle and lower Kissimmee River was 0.21 fish/hour, which was reported as an "all time low" (FWS 1959) for the river. Estimated success rate for largemough bass in the channelized system (both C-38 and the river channel remnants) was 0.28 fish/hour from September through November 1978 and 0.14 fish/hour from December 1978 through February 1979.

Largemouth bass remains the most sought-after species in the Kissimmee River although an increased angling effort for black crappie is evident. Preliminary success rates determined for largemouth bass in the channelized system are similar to those reported as low values in the pre-channelization surveys. Although a decline in the quality of bass fishing is suggested, several aspects of the analysis raise questions. In reporting pre-channelization bass success rates, FWS (1959) did not provide estimates of "normal" success rates or the basis for the determination that the reported success rates represented an "all time low." Collection of additional post-channelization creel data will improve our assessment of current fishing success.

SUMMARY

Realization of maximum sustained benefits from pool marshes, impounded wetlands, and fish breeding canals can be realized only with the expenditure of substantial management resources. Permanent wetlands above control structures (pool marshes) can provide high quality fish and wildlife habitat only if water levels are seasonally fluctuated. Operation of impounded wetlands is contingent upon effective coordination of concurrent land uses and the availability of funds for installation, maintenance, and operation of levees and water control structures. Manpower and specialized equipment are required to optimize the disclimax habitat conditions which are favored by waterfowl. Fish breeding canals require modification to enhance or maintain their value as spawning areas.

While it was understood that the GFC would bear the responsibility for fish and wildlife management expenses associated with C-38 mitigation measures, personnel and budgetary limitations have seriously compromised its ability to meet this commitment. It may be more realistic to view such expenses as a portion of the continuing cost of operation of public works projects. Adoption of this philosophy is essential if optimal benefits are to be realized from fish and wildlife mitigation measures.

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Computer Simulation - A Means of Developing an Aquatic Mitigation Plan[1]

David L. Wegner[2]

Abstract.--Proposed changes to the present flow regime of the Uinta River, requires that a fisheries mitigation plan be developed. Through a computer simulation system, possible instream channel alterations were evaluated in terms of increases in usable fish habitat area. Alternatives were rated as to potential increases in catchable fish and costs of implementation.

INTRODUCTION

To satisfy their biological requirements of reproduction and survival, fish select their habitats for specific stream characteristics. In natural streams the fish move about, seeking the most suitable environment in terms of cover, food, spawning, and other variables. River development projects alter the dynamic character of the streams. Dams and diversions constructed on rivers change their stream flows, velocities, depths, and water quality characteristics. Any alteration of the stream morphology involves subsequent changes in the aquatic species inhabiting the environment.

As biologists and planners, we must anticipate what effect the hydraulic changes will have on the aquatic environment. In the past, the aquatic biologist was at the disadvantage of not knowning what effect a specific instream alteration would have on the aquatic community. The development of the most effective mitigation plan requires that the planner must be able to evaluate alternatives before implementation.

This paper concerns an instream habitat study of a reach of the Uinta River in Utah. The U.S. Bureau of Reclamation is proposing to build the Uinta Dam and Reservior as an integral feature of the Central Utah Project. The project will alter the natural stream flow regime by the regulation of the water for downstream irrigation use.

All available evidence (Mullan 1975) indicates that the lack of adequate stream habitat in the Unita River restricts the size of the annual standing crops and increases the winter and spring mortality of the trout population. The dam will inhibit the natural stream flow regime. Therefore, alternatives to improve the trout habitat below the proposed dan have been investigated.

MATERIALS AND METHODS

Any changes in the river system requires alterations of the river hydraulics and the response of different aquatic species to those changes. The assumption is made that the distribution and abundance of any species is not primarily influenced by any single parameter of stream flow, but is related by varying degrees to all stream flow parameters. The criteria are based on the fact that the individuals of a species will tend to select the most favorable areas if nothing better is available. Under conditions of suitable habitat structure, the distribution of depth, velocity, substrate, and cover are the dynamic pocesses that interact to determine the habitat structure and the distribution and behavior of the fish species.

Personnel of the Cooperative Instream Flow Service Group (IFG), U.S. Fish and Wildlife Service, Fort Collins, Colorado, have developed a methodological approach to analyze these interactions. The IFG incremental method allows for determination of the amount of potential haibtat available for a species and life history phase, in a given reach of stream at different stream flow regimes and channel configurations.

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The method, as applied, is composed of components: (1) hydraulic simulation of the stream reach; (2) determination of depths, velocities, substrates, and cover objects by area; (3) application of habitat evaluation criteria for each species and life stage of species for each flow regime or channel condition under investigation (Stalnaker 1979).

The stream reach simulation utilized by the IFG uses several cross-sectional transects, each of which is divided into 9 to 20 subsections. The computer program treats each subsection as an essentially separate channel for any unobserved discharge or stage (water surface elevation), the mean depth and velocity may be calculated for each subsection in the entire reach over a range of discharges.

To evaluate the magnitude of impacts caused by alteration of the stream channel morphology, a habitat evaluation for each species in question is carried out. Biological criteria primarily focus on parameters of stream flow and channel morphology that affect fish distribution. These include depth, velocity, and substrate. A computerized simulation system (PHABSIM) is available (Milhous 1979). The Uinta River is a steep, braided mountain river. One side channel of the main river was analyzed. Manipulation of the section included: increasing the pool depths; adding a low-head gabion dam and weirs; changing the substrate of the riffles from cobble or gravel; and varying the stream flow throughout the section. A total of six trials were run.

RESULTS

There were six instream alternatives analyzed. Each alternative was tested over four different flow regimes. They included: (1) a constant flow of 10 cfs; (2) a winter flow of 20 cfs and a spring/summer flow of 70 cfs; (3) a winter flow of 20 cfs and a spring/summer flow fo 150 cfs; and (4) a winter flow of 30 cfs and a spring/summer flow of 100 cfs.

The first three hydrographs are indicative of the flows that could be diverted into the side channel. Hydrgraph number four would require a larger winter flow release from the Uinta Reservoir.

The six alternatives are summarized as follows:

Alternative 1 - Original cross-sectional shape and profile. Variable flow regimes were analyzed.

Alternative 2 - The original channel was modified by increasing the pool depths an average of one foot.

Alternative 3 - The original channel was modified by increasing the pool depths an average of three feet.

Alternative 4 - A weir was placed at cross section 1+40. Gravel was placed at the riffle cross sections.

Alternative 5 - Weir at cross section 1+40 and pool depths increased by two feet.

Alternative 6 - Gabion Dam at cross section 1+40 and pool depths increased by two feet.

To evaluate the magnitude of the impacts caused by changing the stream hydraulics, the weighted usable area is determined. The weighted usable area is a habitat index defined as the total surface area having certain combinations of hydraulic conditions, multiplied by the composite use for the combination of conditions (Bovee 1978). This procedure roughly equates an area of marginal habitat to an equivalent area of optimum or preferred habitat.

The amount of weighted usable area available for each life stage of rainbow trout (Salmo gairdneri) was determined over a range of stream flow from 10 to 150 cfs. The 10 cfs was determined as the lowest flow that could be diverted down the side channel. The 150 cfs was the highest flow that could be maintained within the present channel boundaries.

The percent change in weighted usable area between the original and several modified cross sections are shown in Table 1. Each of the Five life stages are analyzed in regard to variable channel morphology, flows and substrate type. Such analysis can be used to identify critical or limiting time periods for each life stage. Changes in the stream characteristics cause differential species reactions.

DISCUSSION

The amount of the weighted usable area offered by each alternative, must be analyzed in reference to the management technique applied to the fishery. The fishery on the Uintah and Ouray Reservation is currenty on a yearly stocking basis. The analysis of the study reached included both a put-and-take fishery and development of a reproducing population.

Table 1. Percent change in weighted usable area for original channel compared to alternative channel design

Original W.U.A.	Life Stage	Percent Change					
		Alt. #1	Alt. #2	Alt. #3	Alt. #4	Alt. #5	Alt. #6
Fry - 2000	10cfs HYDROGRAPH						
Juvenile - 1900	Fry	20	17	15	Flow to Low for Analysis		
Adult - 2100	Juvenile	-25	-44	-50			
Spawning - 600	Adult	-37	-50	-58			
Incubation - 2400	Spawning	-36	-46	-47			
	Incubation	66	61	58			
	20 cfs WINTER/70 cfs SUMMER						
	Fry	- 5	- 4	- 5	0	5	- 3
	Juvenile	-15	-17	-16	28	31	- 7
	Adult	18,62	18,97	27,111	4,114	2,124	3,101
	Spawning	135	78	64	201	167	70
	Incubation	10	6	0	23	21	7
	20 cfs WINTER/150 cfs SUMMER						
	Fry	-12	-10	- 8	-11	-10	-12
	Juvenile	-37	-24	-16	-29	-27	-34
	Adult	18,51	8,66	27,107	4,87	12,102	3,73
	Spawning	30	126	87	143	136	90
	Incubation	23	8	6	24	23	18
	30 cfs WINTER/100 cfs SUMMER						
	Fry	-11	- 6	- 4	-10	- 7	-10
	Juvenile	-23	-17	-17	-16	0	-17
	Adult	12,51	23,78	0,111	27,102	25,112	37,84
	Spawning	104	54	17	149	122	70
	Incubation	16	12	6	16	16	8

To maintain a put-and-take fishery, Alternative No. 5, at 70 cfs summer flow, offers the largest increase in the amount of available area for adult and juvenile rainbow trout. Alternative No. 5 includes the installation of a weir at station 1+40 and pool depths increased by two feet. There is a thirty percent increase in the amount of available juvenile habitat and a one-hundred and twenty-four percent increase in the amount of adult habitat. The flow hydrograph for this alternative supplies an average of 70 cfs to the side channel from April through October. The amount of winter habitat area available to carryover the fish population would increase only two percent. This is the result of low winter stream flow (20 cfs) and the continued lack of large enough pools. By increasing the winter discharge to 30 cfs, an additional twenty-three percent of usable area would be provided.

Establishing a reproducing population of rainbow trout, requires that additional areas for spawning, incubation, fry, and overwintering habitat be provided. The majority of the alternatives provide increases in the amount of adult habitat, however, only Alternatives 4 and 5 at the 70 cfs hydrograph provide increases for all life stages. The smallest increase is in the amount of area available for fry. Therefore, the extent to which the population can develop is limited by the amount of habitat available for the fry development stage. At flows below, 70 cfs the amount of area available for the fry increases, however, the amount of area available for the other life stages is reduced significantly. To increase the amount of available area for fry, areas of shallow (<1.0 ft) water and graveled substrate should be provided (Bovee 1978). Selection of Alternative No. 5 was based on its overall increase in habitat area available to all life stages of the fish.

The designs analyzed represent only a few of the alternatives available. The most logical alternative will be the design which provides the most efficient increase in catchable fish for the money spent. From the cross-sectional and profile data, approximate construction costs for instream alterations can be determined. This allows the planner to develop a cost effective analysis for each habitat improvement option. For Alternative No. 5, with a put-and-take fishery, the cost of excavation of pools and installation of a weir would cost approximately $3,000 (Colorado Department of Highways 1979). This habitat improvement is projected to result in an average increase of 124% in adult trout habitat at a flow of 70 cfs. Either option 4 or 5 may provide for a reproducing population. Addition of gravel to the riffle areas would increase the spawning and incubation habitat by 15% at an approximate cost of $2,000.

The strength of the PHABSIM analysis is in the ability to quantify the alternatives and proposed changes in stream flow and hydraulic geometry in terms of the amount of available fish habitat. Evaluation of the potential impact of water development activities on fish can be made by identifying the life stages and flow levels which may be limiting to the survival of the fish population. The IFG incremental methodology provides a means for the fishery biologist, hydraulic, and hydrological engineers to communicate with each other.

Given the potential changes in the amount of usable area and the associated costs, the biologist/planner can weigh the merits of each possible alternative. There will be trade-offs concerning the costs versus the increase in usable habitat area. However, the biologist will have the tools required to make a logical analysis of the options. The fisheries manager with appropriate analysis should have the capability to arrive at the combination of flows, channel modifications and species that will meet his mitigation/management goals for the most effective cost.

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Congress and the Mitigation of Fish and Wildlife Habitat Losses[1]

William C. Jolly[2]

Abstract.--Authority of Congress for fish and wildlife is defined; Congressional structure for fish and wildlife is identified; Congressional considerations affecting legislation and funding are treated; the FWCA -- is reviewed; the need for wildlife managers to address socio-economic and political environments of the fish and wildlife resource is argued.

Introduction

A current Member of Congress is alleged to have said that the country is in mortal danger whenever Congress is in session. And reminiscent of Ambrose Bierce's definition of a lawyer as "one skilled in circumvention the law" (Bierce, 1906), many people consider politicians and the political process at worst somehow equivalent to evil triumphing over good and in most other cases as explaining why the "right" decisions are not taken. It is a tenet of this paper that such a view of the political process is simplistic, often erroneous, and potentially irresponsible. If biologists, wildlife and fisheries managers, and others presumably committed to protecting and advancing the welfare of fish and wildlife resources elect to remain "pure" and to divorce themselves from the politics of resource conservation, they may, by default, contribute in some measure to a decision, or an action, or a policy less favorable to their concerns than might have obtained. But mere willingness to use the political machinery of government in furtherance of fish and wildlife conservation is not sufficient; one must know enough about the system -- both its structure and its function -- to be able to impact it at the right place and at the right time. The remainder of this paper examines Congress' responsibilities, organization and functions with respect to fish and wildlife resources in general, and fish and wildlife mitigation in particular.

Authority of Congress Over Fish and Wildlife

In the American political system governmental functions are separated according to level, as Federal and State (with some State responsibilities subsequently delegated to local units of government), and according to branch, as Executive, Legislative, and Judicial. Our Constitution reserves to the States all powers not granted to the Federal government. Since responsibility for fish and wildlife is not expressly granted to the Federal government, it is reserved to the States. Hence the historical predominance of the States with respect to resident fish and wildlife species. Federally exercised responsibility for fish and wildlife derives from application of such Constitutionally granted authorities as those governing foreign relations (treaty-making power), interstate and foreign commerce, Federal property, the right to levy and collect taxes, and even promotion of the "general welfare" of the people.

Congress, the Federal legislative branch, enacts legislation to cause things to be done, appropriates funds to pay for doing them, and conducts oversight to monitor how well the mandated program -- even when well-executed -- actually achieves what was contemplated when causative legislation was first enacted. The effectiveness of the Oversight Function depends in the final analysis, of course, on both the power to legislate (i.e., to change a law or to write a new one) and the "power of the purse"

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(i.e., to provide funds or not for given programs, purposes, and even agencies).

Organization of Congress for Fish and Wildlife Matters

Congress is a singular word but a plural reality -- several plurals, in fact. It is composed of two houses and 535 members, supported by over 18,000 staff members. Congress operates, as most know, through a system of Committees. The present Congress, the 96th, has 22 Standing Committees, four Select or Special Committees, and a total of 159 Subcommittees. In the Senate, there are 15 Standing Committees, five Select Committees, and a total of 101 Subcommittees. There are also four Joint Committees and several Commissions and other joint groups serving both House and Senate. Finally, Congress is served by four support agencies: the Congressional Budget Office (with about 200 employees); the Congressional Research Service (about 900 employees), part of the Library of Congress (with 5,200 employees overall); the General Accounting Office (5,300 employees); and the Office of Technology Assessment (about 150 employees) (Brownson, 1979).

Fortunately, one needn't interact regularly with all of the Committees, Subcommittees, Members, and staff to work effectively on fish and wildlife matters. One should bear in mind, of course, that matters considered primarily as "transportation," or "engineering and public works," or "agriculture" -- for but a few examples -- can have significant implications for biological resources. There are times when decisions made in Congressional committees with those jurisdictional interests may have high significance to fish and wildlife. The organizational taxonomy of Congress does not constitute a "natural" taxonomy. However, limitations on time and space indicate my restricting myself to the committees directly charged with responsibility for fish and wildlife resources.

In the House, the legislative committee is the Committee on Merchant Marine and Fisheries presently chaired by Congressman Murphy of New York. The Subcommittee on Fisheries and Wildlife Conservation and the Environment, presently chaired by Congressman Breaux of Louisiana, is the single most important House legislative subcommittee, so far as fish and wildlife are concerned.

In the Senate, jurisdiction over fish and wildlife is not assigned to a single committee but is split. The Committee on Commerce, Science and Transportation, chaired by Nevada's Senator Cannon, has jurisdiction over "marine fisheries." While the Committee does have several subcommittees, it also incorporates a "National Ocean Policy Study" -- NOPS -- under special Senate instruction. Co-chaired by Senators Magnuson of Washington and Hollings of South Carolina, NOPS is directly concerned with marine fisheries issues, especially commercial fisheries. Wildlife and non-marine fisheries fall within the province of the Committee on Environment and Public Works, of which Senator Randolph of West Virginia is Chairman. Iowa's Senator Culver chairs the Subcommittee on Resource Protection which is the most important Senate legislative subcommittee so far as wildlife and fresh water fish are concerned.

Equally important as the legislative committees, however, are the appropriations committees. It makes little difference what wonderful programs are authorized in law if funds are not appropriated to translate the lofty language into action. Not only do the appropriations committees exercise a great deal of influence in determining funding levels for programs including those affecting fish and wildlife, they also exercise real power or "clout" in directing what agencies may or may not, and even must, do in certain areas. The implied threat of fiscal punishment is very real. For instance, at the time of the debate over BLM and Fish and Wildlife Service management of the Sheldon, Russell, Kofa and Cabeza Prieta Game Ranges, in 1974-75, the Administration proposed replacing joint management with single agency management, BLM to be responsible for the Sheldon, Russell and Kofa Ranges, and the Fish and Wildlife Service for Cabeza Prieta. The House Appropriations Subcommittee with jurisdiction over the Department of the Interior unanimously agreed to instruct the Department not to implement the public land orders (making the transfers of management responsibility for the ranges) "until such time as the legislative committees have provided specific authority for such action" (Jolly 1977). The rest is history: the transfers were delayed and Congress soon enacted legislation requiring all units of the National Wildlife Refuge System to be administered through the Fish and Wildlife Service.

The House Appropriations Committee is chaired by Congressman Whitten of Mississippi. The Subcommittee on Interior and related agencies is chaired by Congressman Yates of Illinois. That Subcommittee oversees the budgets of the Fish and Wildlife Service and other agencies of the Department of the Interior, the Forest Service, and several other agencies as well. Obviously, some integration of policy concerns can be assayed at this Subcommittee, since it does not mirror the jurisdictional boundaries of any one or two legislative committees, but of several. The Subcommittee on State, Justice, Commerce, and the Judiciary, chaired by Congressman Slack of West Virginia, is the Subcommittee overseeing the budget of the National Marine Fisheries Service in Commerce's NOAA.

The Senate Appropriations Committee is chaired by Senator Magnuson of Washington. Senator Byrd of West Virginia chairs the Subcommittee on Interior and related agencies; Senator Hollings of South Carolina, the Subcommittee on State, Justice, Commerce, and the Judiciary. These Subcommittees of both the House and Senate correspond directly with the jurisdiction of one another to facilitate meaningful budget review and appropriations actions.

While any number of Members of Congress may support fish and wildlife causes, introduce bills, and have equal votes once legislation and appropriation measures reach the floor for actual enactment consideration, the most significant decisions are made within the Committees and Subcommittees of initial jurisdiction. The members of those committees and especially the chairmen still exercise enormous power over what shall or shall not be considered, and in determining the contents of measures eventually to be voted upon by the Congress. Not to be overlooked are the key staff members of these chairmen and of their committees. Support agencies like the Congressional Research Service and the General Accounting Office are frequently called on to develop analytical and evaluative information, and in getting the most objective appraisals possible of conflicting claims concerning issues and proposed legislation. Supporters of Congressional action favorable to fish and wildlife must know who these influentials are and also their concerns, inclinations, and operating styles if they are to be effective in influencing the politics of resource conservation policy and management. Remember, too, that Congress does not act at the Federal level alone. Many Federal programs are designed to influence State policies, capabilities and efforts as such venerable programs as Pittman-Robertson and Dingell Johnson amply illustrate.

Congressional Considerations Affecting Fish and Wildlife Legislation and Funding

Considerations understood readily by the politically sophisticated often go unappreciated by biologists and others of apolitical backgrounds and perspectives. Those whose professional careers are devoted to direct work with and for fish and wildlife often perceive issues in terms far more black and white than do those in Congress. To a biologist who sees first-hand the destruction of habitat caused by another water resource project, it is crystal clear what should be done. If the project can't or shouldn't be stopped altogether, it should be altered so as to maximally mitigate the damage, and -- almost as a penalty provision -- further compensate by enhancing fish and wildlife resources in some way even if not in exact kind. But our society is pluralistic, and it is intended that Congress reflect and represent that pluralism. The biologist often has the luxury, if you will, of concerning him or herself largely, if not exclusively, with biological resource welfare. Members of Congress must consider a diversity of interests -- ecological, economic, sociological and political. They also bear a responsibility for fiscal concerns. There is never enough money to do all things for all people and the cliché, "one man's boon is another's bane," is no less valid for being a cliché.

As has been indicated, Congress functions as a result of the working of its numerous component parts. It, too, is a system, with complex interconnections or webs of energy and information flow. Legislation and appropriations favorable to fish and wildlife must be conceived, developed, and Congressional approval obtained through a number of steps in parallel, in series, and occasionally, seemingly at loggerheads to one another. If a measure is to be favorably considered by Senator Culver's, or Mr. Breaux's or Mr. Yates'

Subcommittees, it must acknowledge the general and varying specific concerns of these gentlemen, and of at least some of the other members of those Subcommittees. Those concerns reflect basic philosophies, problems and needs of individual States and Congressional Districts, the influence of different supporters and constituents of these people in both their capacities as representative or delegate, and as trustee, as well as they reflect the impartial, objective merit of proposals as best it can be determined. It is valid to distinguish between a holding that a decision not made on the intrinsic merits of a fish and wildlife proposal viewed in isolation is therefore a bad or corrupt or non-meritorius decision, and a holding that such a decision still may be rational, valid and meritorious once it is acknowledged that other legitimate interests and needs and perspectives besides those of fish and wildlife have to be and are included in the decision calculus.

The American political system, afterall, is deliberately inefficient and requiring of decision by consensus as a means of protecting minority rights and minimizing the risk of despotism. Tradeoffs, compromises and outright opposition with respect to some fish and wildlife causes on the part of Members of Congress does not usually mean such people are somehow venal, ignorant, irresponsible, or in some other group's proverbial "pocket." It does mean that our society is complex, that fish and wildlife needs -- representing but a part of our national ecological and social system -- must be and are considered by society in the context of a larger whole, and that the political process of which Congress is but a part is the mechanism by which such consideration is made.

Recent history concerning the Fish and Wildlife Coordination Act itself is illustrative of the points I've tried to make.

The Fish and Wildlife Coordination Act -- Early History and 1974 and 1978 Congressional Hearings [3]

It has long been the opinion of numerous conservation groups and certain State and Federal agencies that fish and wildlife resources have not received adequate recognition and reasonable protection. The Fish and Wildlife Coordination Act now in effect requires that fish and wildlife receive "equal consideration" with other project purposes, provides for the enhancing of the fish and wildlife values, and authorizes compensatory wildlife features where some damage is inevitable. Conservation and protection of the fish and wildlife resources of the United States was recognized as an important problem during the 1930's and several legislative and executive committees were established to study this problem. Formulation of the present Act has occurred over a span of time covering approximately thirty years, specifically, from 1930 to 1958, when it was last amended.

Despite the strength and successes of the 1958 Act, the past twenty years have demonstrated many instances where agency compliance with at least the spirit and in some cases even the letter of the law has been unsatisfactory. In 1970 the then Bureau of Sport Fisheries and Wildlife in the Department of the Interior, dissatisfied with the treatment accorded fish and wildlife interests in water resources planning and development, sought to identify ways of remedying that situation. The Bureau, in cooperation with the State fish and wildlife departments and national conservation organizations, organized a series of symposia to develop stronger recommendations for legislation and policies. The findings and recommendations of these symposia were reviewed and a common report of principal conclusions was prepared and released by the Bureau of Sport Fisheries and Wildlife on behalf of all participants in September 1971. This Action Report (Bureau of Sport Fisheries and Wildlife, 1971) pointed up strengths, weaknesses, and procedural problems of the Fish and Wildlife Coordination Act and of the River Basin Studies operations from both Federal and State viewpoints. The Report also made 169 specific recommendations to fill gaps, eliminate weaknesses, and to take other actions to strengthen consideration of fish and wildlife resources in the water resources development programs. Six of these recommendations were directly aimed at amending the Fish and Wildlife Coordination Act itself. As a result of wide-ranging hearings held in 1971 (U.S. Congress 1971a, 1971b) and 1973 and of comprehensive investigations by the Conservation and Natural Resources Subcommittee of the House

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[3] Much of the material in this section appeared earlier in Jolly, 1977 (pp. 1198-1201).

Committee on Government Operations, that Committee unanimously issued in September 1973 a report entitled "Stream Channelization: What Federally Financed Draglines and Bulldozers Do To Our Nation's Streams" (U.S. Congress, 1973). The Committee Report noted failings of compliance with the intent of the Fish and Wildlife Coordination Act, inadequacies in the Act itself, and among its principal Conclusions and Recommendations, noted that "The appropriate committee of the House of Representatives should consider amending the Fish and Wildlife Coordination Act to (a) extend it to all water resources projects constructed or financed by a Federal agency; (b) insure that Federal and State fish and wildlife agencies are notified at an early stage in project development; (c) require that Federal water resource agencies set forth their reasons for not including in the project any fish and wildlife agencies; and (d) require that estimates of fish and wildlife losses not be evaluated solely in monetary terms."

Finally, there appeared in March 1974 a report by the Comptroller General of the United States presenting the findings and conclusions of a General Accounting Office review of Federal implementation of Sections 2 and 3 of the Fish and Wildlife Coordination Act (U.S. General Accounting Office, 1974). The review was ordered by the Chairman of the Subcommittee on Fisheries and Wildlife Conservation and the Environment of the House Committee on Merchant Marine and Fisheries [then John Dingell of Michigan] because of his long-standing interest in and concern for fish and wildlife conservation and because of the specific recommendations of the previously cited Action Report and "Stream Channelization" report. Principal among the GAO conclusions from its review were the following:

> for the 28 developments reviewed, the act's requirement to consider wildlife conservation equally with other development features had not been effectively carried out. To achieve equal consideration, more effective implementation of the Act's coordination process is necessary.

It was against this background that the House Subcommittee on Fisheries and Wildlife Conservation and the Environment held hearings in June and July 1974 on the GAO findings and recommendations and on several bills which had been introduced to amend the Fish and Wildlife Coordination Act (U.S. Congress, 1974). The hearings drew exceedingly strong support from representatives of the State Fish and Game and Conservation Commissioners, from over thirty Governors, from the Department of the Interior and from many conservation organizations for amending legislation to strengthen the Act. There was some outright opposition to the proposed amendments. The Department of Agriculture was opposed as were the Atomic Energy Commission and the Tennessee Valley Authority. The National Aeronautics and Space Administration believed the proposed legislation was unnecessary and declined to support it. Both the Army Corps of Engineers and the Department of the Interior suggested changes in the legislation as first proposed; in the case of the Corps, its support, or at least neutral acceptance of changes in the existing law, was conditional on certain modifications in the proposed amending law being made.

After reviewing the GAO report and considering the testimony taken in four days of hearings and over several months via correspondence, the Subcommittee reported out an amended version of H.R. 14527 to the full Committee. The full Committee did not act and no further action was taken in the 93d Congress on the measure. From this point on, there is no written record attesting to why the full Committee didn't formally consider the measure and report it out so that consideration by the full House would have occurred. One can be sure that those opposed to the measure conveyed their concerns to the Committee Chairman [then Leonor Sullivan of Missouri].

Perhaps as significant could have been a conceivable judgment on the part of that Chairman that there was little or no likelihood the measure could make its way through the Senate, even if the House approved it, with less than two months remaining in that Congress and pressure to wind up and adjourn mounting each day.

The Hearings and Subcommittee mark-up did serve to identify a number of problems with the Act as it now exists as well as with the proposed changes to the Act. Clearly, however, the proposed strengthening of the FWCA did not have universal support, in the Administration nor outside it. The necessary political support to move a bill all the way through Congress, in competition with other issues and legislation also requiring Congressional attention, was not there.

Last summer, the House Subcommittee on Fisheries and Wildlife Conservation and the Environment devoted three days of hearings to oversight of the administration and effectiveness of the Fish and Wildlife Coordination Act. These were oversight, not legislative, hearings meaning no legislative proposals were under consideration at that time. The purpose was to build a record of facts on which future legislative proposals could be based. The results of those oversight hearings were published (U.S. Congress, 1978) and constitute a public record of the workings, successes and failures, of the FWCA in its 45 year history. Whether or not the 96th Congress considers or acts on fish and wildlife coordination needs remains to be seen. It is probable that at some point, further amendments to the FWCA can be expected. Ultimately, favorable Congressional action will depend on not only demonstrating the problems and failures of the existing law and administrative apparatus, but on showing how proposed legislative and administrative changes can be made to better aid wildlife without actually dismantling or critically obstructing programs responsive to other societal goals.

It is important to realize, too, that failure of Congress to enact changes in the FWCA long sought by fish and wildlife interests does not mean that these concerns have been ignored nor that the efforts for amendment have not borne any fruit. The very fact that Congressional hearings are held, GAO investigations are conducted, and agencies' arguments and records examined in public light can have salutary effects. Not only are problem areas better defined for examination and possible change, but agencies and individuals are sensitized to problems, and put on notice that failure to respond to Congressional concerns and directives can result in bureaucratically painful measures down the road. Finally, it is the rule rather than the exception that major changes in complex areas such as fish and wildlife coordination do not occur quickly, but only over time. While it is hard for a field biologist to understand let alone approve of what seem like inordinate delays in Congressional action, these "delays" are often no more than the necessary and proper ways by which changing societal values are expressed, comprehended, and translated. They are part of the achieving of consensus in a dynamic, never static, environment populated by a pluralistic human society.

Conclusion

I have sought to make a number of points in this perhaps too lengthy discourse. Most important, I think, are the following:

-- the political process by which decisions affecting fish and wildlife are made is not something inherently corrupt or evil but is the means by which a free society attempts to achieve consensus and accomplish societally approved goals in ways respectful of and responsive to legitimate needs of the diverse components of that society.

-- biologists and others dedicated to advancing the welfare of fish and wildlife resources have a responsibility to understand the socio-political-economic systems in order to better apply their expertise and their concerns. There are sins of omission as well as of commission. Failure on the part of knowledgeable fish and wildlife specialists to work and act in the political system may mean that by default others less qualified or less concerned may influence events to the detriment of the resource.

-- Congress is a complicated, often confusing, and sometimes slow institution with respect to fish and wildlife issues as with most others. But it can be comprehended and there are a number of places and times where intelligent input can be made on behalf of fish and wildlife resources. Effectively, supporting these resources in Congress involves far more than just writing your Congressman or getting a bill introduced. Interests and forces unsympathetic or opposed to fish and wildlife causes properly have access to the political process and they know how to use it. Fish and wildlife advocates must be equally sophisticated.

Finally, improvements in the way which fish and wildlife mitigation needs are considered and protected is of interest to Congress, has been seriously monitored and studied over the years, and a factual basis has been laid for future action. The next steps are more political in that support for changes must be demonstrated, the route through Congress (sponsors, Committee chairmen, and selected other influentials) must be prepared systematically, and the support of the Executive Branch obtained (at least its opposition must be prevented). The importance of the fraternity of natural resources professionals in helping state and support legislative goals cannot be overstated. Congress can be very responsive when the needs are properly demonstrated and the necessary political support marshalled.

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The views expressed are those of the author and do not necessarily reflect positions or policies of the Congressional Research Service.

An Analysis of the Proposed Rules to Implement the Coordination Act[1]

Margot Zallen[2]

ABSTRACT.--The prime Federal statute dealing with mitigation is the Fish and Wildlife Coordination Act. The recently proposed rules to implement this Act will have a profound effect on conservation of wildlife resources. These rules are discussed in light of the Act, its legislative history and judicial interpretations. The rules discussed are designed to fill in the details needed to carry out the Congressional intentions in passing the Act.

INTRODUCTION

The Fish & Wildlife Coordination Act, 16 U.S.C. 661 et seq., (the Act) establishes the major environmental review and implementation processes for the fish and wildlife resources affected by water-related projects. Although the Act was first passed in 1934 and was significantly amended by Congress in 1946 and in 1958, the first rules to implement the Act were not proposed until May 18, 1979. They were published in the Federal Register at 44 FR 29300.

Since these rules, when finalized, will have a pervading effect on the conservation of wildlife, they should be looked at in the context of what Congress intended the Coordination Act to do. This paper will do that by discussing the Congressional intent in light of established rules of statutory construction, by examining the language of the statute, its legislative history including the defects of the 1946 Act that were sought to be remedied and judicial interpretations.

The rules must be consistent with the Act and reasonably adopted to carry out the intent of that statute. The purpose of these proposed rules is to fill in the details so that the intent of Congress will be carried out.

ANALYSIS

Section 410.3

The definitions of the terms used in rules are often the key to understanding those rules. This certainly is true of the definitions in §410.3.

"Wildlife Resources"

The 1934 Act was strengthened in 1946 and again in 1958 because of Congress' concern over the Nation's dwindling fish and wildlife resources. It was clearly recognized that the Nation's once abundant and diverse species of fish and wildlife were being seriously depleted. Their habitat was being increasingly degraded and destroyed by man's developments. Protection of habitat was perceived by Congress as the crucial element in conserving fish and wildlife and was the basic premise behind the procedures established by the 1946 and 1958 Amendments. See Hearings (1958); Hearings 1946; S. Rep. 1981; and H.R. Rep. 1944. Although "habitat" is not mentioned in the Act's definition of the terms "wildlife" and "wildlife resources", it was assumed, in the Section by Section analysis of the 1958 Amendments, to be part of the term "wildlife resources" Hearings (1958), p.25.

To further the Congressional intent to protect wildlife by conserving its habitat, the term "wildlife resources" is defined in the rules as including the "biotic and abiotic factors upon which wildlife depends, i.e., habitat." The definition in the Act only covers ". . . all types of aquatic and land vegetation upon which wildlife is dependent." Since there are many other components of wildlife habitat in addition to vegetation and those other components need to be protected if wildlife is to be preserved, the term "wildlife resources" as used in the rules includes all the factors which comprise habitat. This definition allows the main thrust of the rules to be habitat conservation.

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"Action Agency"

Although the Act could have been interpreted to cover other agencies, in practice, the only Federal agencies that have been consulting with wildlife agencies(U.S. Fish & Wildlife Service, National Marine Fisheries Service, and State wildlife agencies) under authority of the Act are those which construct or grant permits or licenses for water-modification projects.

The "action agency" definition in the rules broadens that scope to include the agencies that plan or approve grants, loans, loan guarantees, financial or technical assistance, or contracts for projects. This definition is based on §662(a) of the Act which states that "whenever the waters of any stream or other body of water are proposed or authorized to be . . . modified for any purpose whatever, . . . by any department or agency of the United States . . . such department or agency first shall consult . . . ." (emphasis added)

This action agency definition will lead to more agencies, projects, and wildlife resources being affected by the Act. It also will get the wildlife agencies involved, under the authority of the Act, in certain projects at an earlier and more flexible stage. An example would be a project needing a Rural Electrification Administration loan guarantee that also would need a 404 permit from the Corps of Engineers. There would be early consultation with the wildlife agencies at the loan guarantee stage instead of years later when the application for the 404 permit was made.

"Enhancement"

The terms compensation, conservation, enhancement, loss prevention, and mitigation are differentiated in these definitions. The legislative history is replete with indications that Congress recognized that enhancement (development and improvement) was different from conservation, loss prevention, and mitigation. It intended that the 1958 Amendment clarify that wildlife agencies were authorized to study and/or recommend enhancement measures and that action agencies were authorized to implement such measures. It had not been clear under the 1946 Act that they could do so. The Fish and Wildlife Service had testified that it was not sure it even had the authority to suggest enhancement measures and construction agencies had maintained that without particular authorizing legislation they did not have the authority to enhance fish and wildlife at water-resource projects. To clear this up and to encourage the adoption of such measures, the 1958 Amendment granted specific continuing authority for enhancement measures. E.g., Hearings (1958), pp.19, 24, 26; S. Rep. 1981, p. 4.

"Project"

One of the continuing problems with conserving wildlife resources impacted by water-resource projects is that wildlife agencies have not been participating in the planning of such projects. They often are confronted with finalized plans when they are consulted about wildlife resource mitigation. At this stage it is difficult to provide meaningful input or to modify projects. Congress intended to solve this problem in 1946 by amending the 1934 Act to provide that the Federal agencies "first shall consult" with the wildlife agencies. H.R. Rep. 1944, p.3.

However, this solution was not the answer and in 1958 Congress was still concerned with the lack of adequate wildlife resource conservation because wildlife agencies were not involved in the earliest stages of project planning. They were called in after the action agency was well along in its planning process. Congress recognized that biological studies took time and that by being consulted late wildlife agencies often were pressured into acting too rapidly. This resulted in inadequate protection of wildlife resources. Conservation measures were being suggested too late to be incorporated into project plans. Hearings (1958), pp.19, 20; H.R. Rep. 2183, p.2. It was believed that if the wildlife agencies began their investigations early so that the plans of the wildlife agencies and the construction agencies could grow together and be coordinated with each other, more wildlife resources would be conserved. E.g., Hearings (1958), pp.7, 19, 26.

To effectuate such early participation, Congress amended the Act in 1958 to add that whenever there was a "proposal" to modify a water body, wildlife agencies should be consulted first. Before that 1958 Amendment, the Act only had applied at the authorization stage of a project and not at the earlier proposal stage.

Since wildlife agencies still have not been participating in the early planning phases of proposals for water modification projects, the phrase "planning process which could condition an action" was made part of the definition of project. This was included to ensure that whenever the term "project" is used throughout the rules, it connotes all stages of a project including the initiation of planning.

Section 410.22

One of the reasons that wildlife agencies have not had sufficient early participation in project planning is that there have not been adequate or uniform procedures for such involvement. The compliance procedures in the rules provide the needed procedures.

The first part of the compliance procedures, the consultation process, emphasizes such wildlife agency involvement at an early stage. Such involvement is required for: 1) applicants for approvals which may have a significant impact on wildlife resources; 2) action agencies upon initiation of planning studies or actions which may lead to the authorization of a Federal project; and 3) action agencies upon their initiation of planning for modification or supplementation of project reports on previously authorized projects.

Section 410.21

The rules emphasize that equal consideration of wildlife resource values is the essence of complying with the Act. The requirement for equal consideration of wildlife conservation, added by the 1958 Amendment, was purposely inserted to eliminate one of the major deficiencies in the implementation of the 1946 Act. In 1946, Congress wanted to give greater protection to wildlife resources, however, conservation was still subordinate to other project purposes. By 1958, it was clear that by giving action agencies complete discretion as to the level of consideration of wildlife resources, those resources were not being protected. Compare Hearings (1946), p.6-9, and H.R. Rep. 1944 with Hearings (1958). This problem was to be remedied by providing fish and wildlife "full partnership in water-resource development projects", by providing "that wildlife conservation shall receive equal consideration" with other features of water-resource development. See Hearings (1958), p.7. This was to "have the effect of putting fish and wildlife on the basis of equality with flood control, irrigation, navigation, and hydroelectric power in our water-resource programs, which is highly desirable and proper, . . ." S. Rep. 1981, p.5. This equal consideration mandate has been interpreted as a declaration of the Congressional purpose that underlies the Act, *Sierra Club v. Morton*, 400 F.Supp. 610 (D.C. Cal. 1975).

The Act does not state how equal consideration should be carried out, but in §661 of the Act, it is implied that equal consideration could be accomplished through a process, namely the coordination of wildlife resource conservation and rehabilitation "with other features of water-resource development programs through . . . effectual and harmonious, planning, development," and "maintenance."

The rules establish that implementation of the equal consideration mandate is to be accomplished through the process of the rules' detailed compliance procedures. By stating that the fulfillment of the compliance procedure (consultation, reporting, full consideration, and implementation) is required by the equal consideration mandate, the rules make concrete what previously had been treated as a vague concept. Such early and continued participation is required by the Act so that the adverse effects on wildlife resources can be prevented, compensated, or minimized. See *Texas Committee v. Alexander*, unofficially reported in 12 ERC 1676 (1978), *Environmental Defense Fund v. Foehlke*, 473 F.2d. 346 (8th Cir. 1972).

Section 410.12(b)

Section 410.12(b) of the rules states that the compliance procedures of the rules apply to modification or supplementation of plans for previously authorized Federal projects. Recently, this point was directly ruled on in a case where industrial water marketing was proposed for a reservoir that had been authorized for irrigation purposes. The U.S. District Court had ruled that the Act did not apply to this water marketing proposal because the Act is "designed to apply to new project construction and has no application to operation and programs under previously constructed projects." See *Environmental Defense Fund v. Andrus*, 420 F. Supp. 1037, 1049 (D.Mont. 1976). The 9th Circuit Court of Appeals overruled that finding and stated "the clear language of the statute shows that the Act applies to 'modification or supplementation of plans for previously authorized projects'." *Environmental Defense Fund v. Andrus*, No. 76-3133 (9th Cir., filed April 18, 1979). This ruling is significant because the water marketing plan was not submitted to Congress as a project modification but was merely a plan to change the reservoir's operation.

Section 410.11(c)

In regard to exemptions from the Act, the rules simply restate the exemptions specified in the Act. The legislative history clarifies the reasons behind two of these, the 10-acre impoundment and Federal land management exemptions. The Section by Section analysis of the 1958 Amendment states that the purpose of the exemption for 10-acre impoundments was primarily to exclude stock watering ponds and tanks. Hearings, (1958) p.28. That analysis explains that the purpose of making the Act inapplicable to land management programs conducted by Federal agencies on Federal lands was to exclude activities, such as "logging and road building on national forests where control of water, if any, would be incidental."

Section 410.24(b)(1)

Section 410.24(b)(1) states that the result of regarding wildlife conservation measures as a programmatic and project purpose equal to other project purposes may be that certain of the potential project benefits may be diminished. This statement is supported by the legislative history of the 1958 Amendment. It was pointed out that conservation measures "may entail changes in the overall plans," H.R. Rep. 2183, p.2, and that full benefits may have to be foregone to accomplish wildlife conservation measures. Hearings (1958), p.26. This need to diminish project benefits was understood and accepted by Congress for previously authorized projects as well as for those that might be authorized in the future, Hearings (1958), p.26; S. Rep. 1981, p.4. This was in sharp contrast to the Congressional intent in 1946. Although in 1946, Congress was interested in giving Federal assistance to wildlife resources, it did not intend to curtail project benefits for the sole benefit of wildlife resources, Hearings (1946), H.R. Rep. 1944, p.3.

Section 410.24

One of the ways that the Act provides for effectuating wildlife conservation is by the wildlife agencies reporting on the wildlife aspects of a project and making recommendations on wildlife resource conservation needs. The action agencies then must give those reports and recommendations full consideration and take wildlife conservation into account in their decisionmaking process. See *Zabel v. Tabb.* 430 F.2d 199 (5th Cir. 1970). The Supreme Court, in *Udall v. FPC,* 387 U.S. 428, 443 (1967), has stated that the action agencies have a duty to explore and evaluate the wildlife resource conservation aspects of a project. In order to ensure that action agencies give such full consideration to fish and wildlife resources, the rules in §410.24 establish the procedures that must be incorporated into the action agencies decisionmaking process.

Section 662(b) of the Act requires action agencies to include "such justifiable means and measures for wildlife purposes as the reporting agency finds should be adopted to provide maximum overall project benefits." The lack of uniform interpretation of this sentence has caused a great deal of controversy and confusion. The rules, in §410.24(b), stress that monetary benefit-cost ratios are not to be used by action agencies in their decisionmaking process when determining whether conservation measures are justified. This interpretation is supported by the Senate Committee Report which states "(i)t is the understanding . . . , that these measures would not have to be justified under the usual benefit-cost type of analysis. They would not produce 'benefits'. These measures would be for reducing or compensating for losses." S. Rep. (1981), p.4. Monetary benefit-cost justification was not deemed feasible because of "the inherent difficulty in assigning a monetary evaluation to losses to fish and wildlife, whose value is basically, intangible." See Hearings (1958), p.27. In order to measure the effect a project may have on wildlife, not the effect it will have on people, the rules require that the assessment and evaluation of justifiable conservation measures are to be based on wildlife habitat values and not on human use or dollar values. This requirement will provide a more uniform basis for justification of conservation measures. However, the rules do not prevent the use of monetary evaluations, such as those based on user days as long as they are not used to justify the adoption or rejection of conservation measures.

The Act also requires action agencies to estimate project-related benefits or losses for Federal projects. It also was Congress' understanding that this "estimation of wildlife . . . losses . . . would not require a dollar evaluation." S. Rep. 1981, p.4. The rules are consistent with this understanding and require in §410.24(a)(1)(ii) that losses to wildlife resources be measured in terms of wildlife resource productivity.

The rules also establish procedures to govern the action agency decisionmaking process by setting forth the reasons that cannot be used by action agencies in rejecting wildlife agencies' recommendations. The rationale behind this requirement is that when the decision on what wildlife resource conservation measures are justifiable is based on considerations other than what is needed to conserve wildlife, wildlife resource needs are not given full consideration. This results in unequal consideration. To ensure that such full and equal consideration is given, the rules provide for disclosure of the action agency findings, the basis for such findings, and opportunity for public scrutiny and participation.

Section 410.31

Section 410.31 calls for wildlife agencies to be available to testify concerning Congressional action on wildlife conservation measures for Federal projects. In the past, these agencies have not taken an active role in explaining their recommended conservation measures to Congress. Congress had expected that one of the results of the 1958 Amendment would be that it would be better informed about the impacts to fish and wildlife that would result from Federal water projects and that it would decide which conservation measures would be incorporated into these projects. See Hearings (1958), p.18; H.R. Rep. 2183, S. Rep. 1981. Congress will be better informed if wildlife agencies testify and explain the reasoning behind their reports and recommendations. It then can independently evaluate the conservation measures that should be incorporated into projects and will have additional information to use in deciding to agree with or override an action agency's decision on whether wildlife agencies recommendations should be adopted.

Section 410.32

Section 410.32 organizes procedures for General Plans, that are established in §§ 3 and 4 of the Act, for the lands that are to be managed for wildlife conservation purposes.

These lands include those specifically acquired for wildlife conservation purposes and those acquired for other project purposes that are suited for wildlife conservation. Hearings, (1958), p.28. The matter of the inclusion of project lands to be administered according to a General Plan is covered in the definition of "wildlife resource properties." It states such properties include lands, waters, or interests therein "otherwise set aside by Federal agency for the conservation of wildlife resources."

Note that neither the Act nor the rules provide for the current practice of a separate license agreement between the action agency and a State in addition to a General Plan. Since the document which transfers the land is to be approved at the same time as the General Plan, a later license would be superfluous. General Plans will be more detailed than in the past and any factors that have been covered by licensed agreements will have to be included in the General Plan.

CONCLUSION

The sections of the proposed rules that are discussed are illustrative of the manner in which the rules provide the procedures to implement the Act. They are consistent with the Act and fill in the needed details so that the Congressional intentions in passing the Act can be realized. The language of the Act and the interpretations of that language provide a firm foundation for the implementation of such intent.

REFERENCES CITED

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NEPA Regulations, A New Tool for Achieving Better Mitigation[1]

Gene A. Whitaker[2]

Regulations to implement the National Environmental Policy Act (NEPA) issued by the President's Council on Environmental Quality on November 29, 1978, become fully effective on July 30, 1979. They are binding on all Federal agencies requiring, in part, that agreed-to mitigation be implemented as an integral part of all actions. Agencies must also condition grants, permits or other approvals to assure implementation of mitigation measures. All Federal agencies must invite other agencies and the public to participate in their planning activities and seriously consider all suggested mitigation measures. The responsibility is with other agencies and the public to participate in early planning and to provide sound advice. If adequate mitigation is not incorporated in a project plan the President's Council on Environmental Quality can be asked to intervene.

The National Environmental Policy Act (NEPA) (42 U.S.C 4371 et seq.) requires that during project planning all practicable habitat mitigation measures be studied and that agreed to mitigation measures be carried out. These are part of the new Regulations for Implementing the Procedural Provisions of NEPA (40 CFR 1500-1508), hereinafter referred to as the NEPA Regulations. The NEPA Regulations strengthen NEPA by detailing the procedures all Federal agencies must take to comply with the Act. The NEPA Regulations are fully effective on July 30, 1979, and binding on all Federal agencies. They define what all agencies shall do to comply with NEPA. They replace the 1973 CEQ Guidelines. The existing individual agency guidelines (±70) are being revised and updated to conform to the new Regulations.

BACKGROUND

The environmental movement in the 1960's culminated in the passage of NEPA which is widely recognized as our basic national charter for protection of the environment. The policies and goals of Section 101 of NEPA state clearly that Federal agencies should, as part of everything they do, consider the potential environmental effects and use all practical means necessary to avoid environmental degradation. To assure adequate consideration of thes environmental goals as part of project planning the authors of the Act included in Section 102. (2) eight "action-forcing" provisions.

In considering the requirements of NEPA, people frequently think only of Environmental Impact Statements (EIS) required by Section 102 (2)(C) .

The EIS has become the most visible aspect of NEPA. As a result of numerous court actions many Federal agencies tend to emphasize the development of legally sufficient EIS's to satisfy the law and have often failed to give due consideration to Section 102(2)'s other important provisions designed to make agency planning and decisionmaking more responsible to environmental concerns. As a result, the EIS has tend to become an end in itself rather than a means of making better decisions. Our goal as individuals and as representatives of organizations concerned with the maintenance of quality wildlife habitat is to ensure that decisionmakers have adequate information and give adequate consideration to fish and wildlife resources and to see that unavoidable habitat losses are promptly mitigated.

To accomplish this it is necessary to work directly with those planning an action in the early stages of project conception. Information and suggestions provided early can receiv ull consideration and be part of the final lanning and environmental documentation on nich a later decision will be based. If the oncerns of fish and wildlife interests, such ; the need for adequate mitigation, are not ccurately reflected and taken into account nere needs to be an opportunity for direct nput of a third party prior to the final ecision documents. Once there has been an greement as to what will be done, past history as clearly shown that special provisions are eeded to see that mitigation measures are arried out. Without this safeguard, some of ne best intentions do not reach meaningful uition.

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It is often difficult to have wildlife lues adequately considered and all losses tigated as part of a Federal project. It ver will be an easy task. However, the new PA Regulations can help.

PURPOSE

The purpose of the NEPA Regulations, as ated in Section 1500.1, "is to tell Federal encies what they must do to comply with the ocedures and achieve the goals of the Act." is clearly stated in Section 1500.1 that PA's purpose is not to generate paperwork - en excellent paperwork - but to foster cellent action. The NEPA process is intended help public officials make decisions that based on an understanding of environmental nsequences, and take actions that protect, store, and enhance the environment." The PA Regulations specifically require (Section 02.16(h)) that an EIS "Include appropriate igation measures not already included in proposed action or alternatives." As stated the introduction to the Proposed FWCA Implenting Regulation (44 FR 98, page 29301) PA's requirement that wildlife impacts and igation alternatives be considered in environental impact statements carries with it the igation to undertake mitigation activities the fullest extent possible in order to ieve the goals of Section 101."

How to define the term "mitigation" is ething few have been able to agree on. The A Regulations now give us a definition for in project planning and environmental docut. Section 1508 states that,

"Mitigation" includes:

Avoiding the impact altogether by not ing a certain action or parts of an action.
Minimizing impacts by limiting the degree magnitude of the action and its implementan.
(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
(e) Compensating for the impact by replacing or providing substitute resources or environments.

FWCA requires a more definitive breakdown of this definition. The proposed FWCA Regulations subdivide this all-encompassing definition and define loss prevention, mitigation, and compensation as separate terms. In this discussion I use the term mitigation in a general sense as defined in the NEPA Regulations.

PROJECT PLANNING

The NEPA Regulations require all agencies to integrate the NEPA process into all of their planning activities. This will help assure that fish and wildlife habitat, as well as other environmental values, receive adequate consideration during early planning. To make the planning process an open one, agencies are required to notify the public (Section 1506.6) early in planning and to involve them in the process. (All Section references, not otherwise identified in the remainder of this paper refer to 40 CFR 1500-1508). For major projects, those requiring an EIS, agencies are required to utilize (Section 1501.7) an "early and open process," termed "scoping" to see that all important issues and alternatives, including potential mitigating measures, are considered during the planning process. The lead agency must invite all of the potentially affected public and private groups and (Section 1501.7 (a)(1)) "other interested persons (including those who might not be in accord with the action on environmental grounds), . . ."

The NEPA Regulations also require any Federal agency with jurisdiction by law over any aspect of a proposed action (such as the FWS has under the FWCA in certain instances), if requested, to be a "cooperating agency." (Section 1501.6). A cooperating agency has the privilege of having their views considered and proposals utilized early in planning. No agency can refuse a request to be a cooperator without explaining why in a letter to the agency. A copy of that letter must be sent to CEQ. Cooperating agencies also have the responsibility to provide the lead agency with their views and information early in the planning process and to participate in the scoping process. They also are to assist the lead agency in preparing environmental analyses as part of the planning team as time and funds permit.

The results of the planning effort including mitigation measure plans must, of course, be recorded in the EIS and other project documents. The EIS must also (Section 1502.25), to the fullest extent possible, be prepared "concurrently with and integrated with environmental impact analyses and related surveys and studies required by the Fish and Wildlife Coordination Act. . .and other environmental review laws and executive orders." The NEPA Regulations allow an EIS and other environmental documents to be combined with any other document used in agency planning and decision-making (Section 1506.4). Several agencies have, and I am sure more will, take advantage of this to reduce paperwork and time delays. For we concerned with obtaining mitigation having all the information for a project in one document at one time for review will simplify our job.

As you can see, wildlife interests should now have ample opportunity to provide input into planning activities. There will be more opportunity than any one group can provide. During the last six months several agencies have started using the scoping process. The Federal Register daily carries invitations to several scoping meetings, often more than a dozen, in the United States. One for a power plant siting study in the upper midwest involved meetings and field examination of three sites in two States and took a full week. One power plant project in Kentucky has had several multi-day meetings. Planners for an Environmental Protection Agency sewage treatment proposal on Martha's Vineyard off the coast of Massachusetts have called almost monthly scoping meetings. The opportunity is there. The challenge will be how to use our personnel resources to the best advantage. If we don't make our concerns known when asked it will be difficult to criticize later.

If all interests have worked together harmoniously in planning a project the proposed action and its major alternatives will include all practicable mitigation measures. If not, reports and suggestions provided earlier will provide a good basis for a final report on project and for comments on the environmental analyses that will become part of the final EIS.

PRE-DECISION REFERRALS TO CEQ

If, despite our best earlier efforts, an agency in its final EIS states it intends to go ahead with a project that, in the view of another Federal agency, is environmentally unacceptable CEQ can be asked to arbitrate (Section 1504 - "Pre-decision Referrals to the Council of Proposed Federal Actions Determined to be Environmentally Unsatisfactory.") The lead agency cannot make a final decision on its proposal and proceed with its implementation until the referral process is completed. These procedures were developed in response to Executive Order 11991, May 24, 1977, which amended E.O. 11514, "Protection and Enhancement of Environmental Quality," and direct the preparation of procedures, (Section 3(h)(2)) "for the Referral to the Council of conflicts recommendation as to their prompt resolution." Proposed project actions can be referred if there are serious adverse environmental impacts that represent a probable violation of national environmental standards or policies, would set an important precedent, or if environmentally preferable alternatives are available. Failure to include needed and feasible mitigation measures appears to us to be adequate reason for considering a CEQ Referral.

The Fish and Wildlife Service through the Department of the Interior has invoked this procedure obtaining substantial project modifications to mitigate habitat losses in the past 18 months. Of utmost importance is the fact that this new procedure is available. Several times, recently, we have obtained significant improvements in proposed projects just by notifying an agency that we were considering recommending a Referral.

The Referral process is to be used ". . . only after concerted, timely (as early as possible in the process), but unsuccessful attempts to resolve differences with the lead agency."

The Referral process emphasizes the intent of the NEPA Regulations that all agencies should work together early in the planning process to resolve differences. If wildlife agencies don't work with lead agency planners early to point out the need for mitigation the option to Refer the proposed project to CEQ later will be seriously compromised.

The NEPA Regulations (1504.3(e)) also provide an opportunity for members of the general public and conservation organizations to become involved in the process by giving their views in writing to CEQ in support of a Referral. This generally requires close cooperation with the initiating agency. All letters, as well as all the material from the referring agency, must be received by CEQ within 25 calendar days of the day the Environmental Protection Agency publishes the notice of availability of the final EIS in the Federal Register unless the lead agency grants a time extension.

A Referral should be considered only as a last resort means to get needed mitigation incorporated in a project plan. All other procedures, such as those to be developed under the FWCA Regulations should if possible be utilized first.

DECISIONMAKING

At the end of the integrated planning and NEPA process the lead agency must make a final decision as to what it will allow or recommend that Congress authorize. Immediately after that decision is made the lead agency must finalize a concise public Record of Decision (ROD) stating exactly what they intend to do and why. In it they must, according to Section 1502.2 of the NEPA Regulations; "state whether all practicable means to avoid or minimize environmental harm from the alternative selected have been adopted, and if not, why they were not."

Section 1502.2(e) further requires that for all actions that required an EIS, a monitoring and enforcement program for any agreed-to mitigation shall be adopted. This program must be summarized in the Record of Decision. Section 1505.3 expands on this important requirement saying,

"Mitigation (Section 1505.2(c)) and other condititions established in the environmental impact statement or during its review and committed as part of the decision shall be implemented by the lead agency or other appropriate consenting agency. The lead agency shall:

"(a) Include appropriate conditions in grants, permits or other approvals.
(b) Condition funding of actions on mitigation.
(c) Upon request, inform cooperating or commenting agencies on progress in carrying out mitigation measures which they have proposed and which were adopted by the agency making the decision.
(d) Upon request, make available to the public the results of relevant monitoring."

This requirement, so explicitly stated, should solve a major concern of many at this conference. Once we have worked and seen to it that adequate mitigation measures are included in a proposal it is up to the lead agency to see to it that the agreed-upon measures are adequately carried out in a timely fashion. The basic responsibility for implementing NEPA and its requirements rests with the lead agency. However, the real thrust of NEPA and its implementing regulations are to allow other agencies and concerned members of the public to become involved and be able to soundly influence lead agency decisionmaking in a manner that is environmentally sound.

IMPLEMENTING THE NEPA REGULATIONS

The NEPA Regulations require each Federal agency to develop and promulgate implementing procedures prior to the July 30, 1979, effective date. There are certain items (Section 1507.3) that must be included in agency implementing procedures. Agencies may also explain how certain requirements of the Regulations relate to their existing operating procedures. However, an agency cannot change or even paraphrase the NEPA Regulations in their implementing procedures.

It was not until development of the implementing procedures that most agencies began to fully recognize the full impact that the NEPA Regulations will have on their planning and decisionmaking. The results have been a considerable delay and difficulty within most agencies in finalizing their procedures.

I encourage you to look closely at each agencies' implementing procedures and if you have problems with them write the agency. If CEQ determines that an agency's final procedures do not conform to the requirements of the NEPA Regulations they will publish a comment memorandum in the Federal Register outlining the deficiencies.

It is the implementing procedures that will tell you exactly how to gain entry into the early planning process and obtain notices of meetings and copies of environmental documents. Other Federal, State and local agencies and private organizations will generally be able to be placed on direct mailing lists by request rather than having to read the Federal Register every day.

THE CHARGE

The NEPA Regulations put the responsibility on the lead agency to:

1. Invite everyone to become involved in their planning.
2. Utilize ecological information provided.
3. Address all suggested mitigation measures and for those not used explain why they were not.
4. Make all information including public comments and other agency reports available to the public and the decisionmakers.
5. See to it that agreed-to mitigation measures are installed as part of a project and maintained.
6. Monitor the effectiveness of installed mitigation meassures and provide reports as to their effectiveness as requested.

HOWEVER, the responsibility is with us, as representatives of Federal and State wildlife agencies, conservation organizations and concerned citizens, to work with lead agencies.

Elements of a Policy on Mitigation of Environmental Damages in Michigan [1]

Douglas B. Jester Jr.[2]

Thomas R. Doyle[3]

Mitigation is emerging in policy discussions within the Michigan Department of Natural Resources as a means of offsetting costs imposed on the public trust in natural resources by conduct which impairs or damages natural resources but is otherwise in the public interest.

INTRODUCTION

The Michigan Department of Natural Resources is the department of state government charged with protecting the natural resources of the state, and the public trust therein, from pollution, impairment, or destruction. Mitigation is emerging as an important part of the Department's strategy in performing this mission. Hence, we have worked for some time to develop an appropriate policy on mitigation of environmental damages in Michigan. In this paper, we review some probable elements of this policy and attempt to shed some clarifying light on the concept of mitigation as it relates to the public trust.

THE STRATEGIC CONTEXT FOR MITIGATION

The organic act of the Michigan Department of Natural Resources, Act 17 of the 1921 session of the Michigan Legislature, provides that the Department "shall protect and conserve the natural resources of the state of Michigan; . . . ; prevent and guard against the pollution of lakes and streams within the state, and enforce all laws provided for that purpose with all authority granted by law, and foster and encourage the protecting and propagation of game and fish."

Other state and federal laws have given to the Department substantial authority with which to protect natural resources. Most of these laws provide for prohibition or restriction of certain general categories of conduct.

Much broader authority is given to the Department by the Michigan Environmental Protection Act (Act 127 of the 1970 session of the Michigan Legislature) which provides that "In any . . . administrative, licensing or other proceedings, and in any judicial review thereof, any alleged pollution, impairment or destruction of the air, water or other natural resources or the public trust therein, shall be determined, and no conduct shall be authorized or approved which does, or is likely to have such effect so long as there is a feasible and prudent alternative consistent with the reasonable requirements of the public health, safety and welfare." It is quite clear from this that the Department is required to consider all effects on natural resources of conduct for which authorization or approval is required and that authorization may be withheld even though the specific statutory and administrative rules requirements of authorization are met.

Further, the Michigan Supreme Court, in Westervelt v. Natural Resources Commission, a case involving the authority of the Department to regulate excessive use of a stream by canoeists, has construed the organic act of the Department and the Michigan Environmental Protection Act to authorize the Department to promulgate rules for regulation of conduct which is harmful to natural resources even in the absence of specific statutory authority for any regulation of such conduct by the Department.

The Michigan Department of Natural Resources clearly has both the mandate and the authority to insure that the natural resources of the state, and the public trust therein, are not impaired or destroyed unless there is no feasible and prudent alternative to do that which is in the public interest. Before this can be translated into policy, however, it is necessary to inquire further into the concept of public trust.

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THE PUBLIC TRUST

Although the public trust is a difficult legal concept which is subject to much more interpretation by the courts, it apparently consists of two main elements: first, that conservation of natural resources is of paramount concern, even at the expense of present use; second, that the highest and best use of natural resources is that which provides a continuing stream of public benefits without impairing possible future uses.

Perhaps the best interpretation of the first element is exemplified by the protection given to endangered species by both United States and Michigan law; these essentially provide that destruction of a natural resource is not permitted unless the consequences of avoiding that destruction are unbearable.

Michigan's courts, interpreting the constitutional provision (Article IV, Section 52 of the Michigan Constitution of 1963) that "conservation and development of the natural resources of the state are . . . of paramount public concern", have not permitted any agency of state government or even the State Legislature to authorize destruction or removal of natural resources from the public trust without first finding that there is and will be no public benefit to be derived from the resources. This is a very stringent standard and we believe that even the courts will bend from it to permit such conduct when the consequences of its prohibition are unbearable.

The second element is more an interpretation of legislative and administrative action than of law, for the courts have not yet had the opportunity to act upon it. It suggests that the "paramount public concern" for natural resources is so great that impairment or destruction of natural resources, whether in private or public ownership, cannot be permitted if it results in even a temporary loss of significant public benefits derived from those resources. This principle is perhaps best represented in public policy by the priority of public recreation in the management and use of forests, fish and wildlife.

MITIGATION AND THE PUBLIC TRUST

In light of the foregoing analysis, we suggest that the Michigan Department of Natural Resources may not authorize or approve any development or conduct which will or is likely to impair or destroy the natural resources of the state, or the public trust therein, unless:

1) there is no feasible and prudent alternative;
2) all feasible measures to reduce adverse impacts have been exhausted;
3) all feasible measures to counteract adverse impacts have been exhausted;
4) all feasible measures necessary to insure an unimpaired flow of public benefits from natural resources have been incorporated; and
5) the consequences of not permitting or of further reducing the impairment or destruction of natural resources are unbearable.

Those readers familiar with the practice of mitigation will note that most, if not all, of the measures normally used to mitigate adverse effects on fish, wildlife, and other natural resources fit within this framework. The policy we have enunciated, however, provides a clear priority for the kinds of measures to be used: namely, measures to prevent adverse effects, measures to counteract adverse effects, and measures which provide substitute or enhanced public benefits. It also provides that, to the greatest possible extent, these measures provide full compensation for damage to natural resource values.

Although we have argued our case through interpretation of Michigan law and public policy, we are confident that the same legal concepts are available in the laws of most states. We also believe that the proposed policy offers the clearest possible standard for maintaining the difficult balance between conservation of natural resources and other aspects of the public interest. As stewards of the people's natural resources, this is the least that we can do.

LITERATURE CITED

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Wildlife Resources and Project Design Under New Federal Planning Initiatives[1]

R. Charles Vars, Jr.[2]

Abstract.--An economic analysis of the proposed rules to implement the Fish and Wildlife Coordination Act, the Habitat Evaluation Procedures, and the Water Resources Council's proposed manual of procedures to evaluate project benefits and costs shows that these initiatives will make unacceptable some projects that would be acceptable under current evaluation procedures, reduce the habitat damages associated with some selected projects, but lead in some cases to the selection of project plans with larger wildlife habitat damages than under current procedures.

INTRODUCTION

The publication of three documents in 1979 will have important consequences for the conservation of wildlife resources and the design of Federal water resources development projects. The Department of the Interior will publish rules to implement the Fish and Wildlife Coordination Act (FWCA Rules) and revised Habitat Evaluation Procedures (HEP Procedures). The Water Resources Council (WRC) will publish a Manual of Procedures for Evaluating Benefits and Costs of Federal Water Resources Projects (Manual).

This paper presents an economic analysis of the effects of the Rules and Manual on wildlife resource conservation and project design. The first section outlines the major relevant features of the review draft versions of each publication. The second section analyzes the impact of Manual and Rules within a conceptual framework based on the WRC Principles and Standards for Planning Water and Related Land Resources (P&S) and the fundamental model of choice. Findings are summarized in the concluding section.

MAJOR FEATURES OF PUBLICATIONS

FWCA Rules

The purpose of the proposed FWCA Rules is to ensure that wildlife conservation is fully considered and weighted equally with other project features in agency decisionmaking processes by integrating such considerations into project planning, financial and economic analyses, and project implementation. The Rules require Federal agencies which plan, construct, operate, or maintain water resource project to include in project plans such means and measures for wildlife conservation as they may find justifiable to obtain maximum overall project benefits to the public. More specifically, the Rules:

1. require the use of techniques based on habitat values as the means for assessing impacts on wildlife resources and for evaluating wildlife conservation measures;

2. ensure that benefit-cost analyses of alternative project plans include the construction, acquisition, operation, maintenance, and replacement costs of conservation measures, and, to the extent they are quantifiable, the costs of uncompensated wildlife resource losses; and

3. require agencies to explain why they deem conservation measures recommended by wildlife agencies for compensation of wildlife resources are not justifiable.

The definitions provided in the Rules will be used in this paper. 'Compensation' means completely offsetting losses to wildlife resource values using measures described in the NEPA regulations. 'Conservation' means wildlife loss prevention, mitigation, conservation, compensation, and enhancement. 'Enhancement means development or improvement of wildlife resource values of the area affected by the project beyond that which would occur without the project. 'Loss prevention' means designing and implementing a project to avoid adverse impacts on wildlife resources. 'Mitigation' means

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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(1) lessening wildlife resource losses to a project through use of loss prevention measures and (2) offsetting losses through the use of other structural and nonstructural measures.

Habitat Evaluation Procedures

The HEP Procedures provide a technique of the type required by the FWCA Rules for assessing project impacts on wildlife resources and evaluating wildlife conservation measures. The Procedures postulate that all land and water habitat has some value to fish and wildlife and this value can be determined by observing physical characteristics of the habitat. The potential productivity of a habitat is estimated by measuring the parameters of the habitat rather than its present or potential fish or wildlife population.

The basic unit of HEP analysis is "habitat type" defined in terms of vegetative structure and plant species composition for terrestrial environments and physical and chemical characteristics for aquatic environments. Habitat types are selected so that their physical and/or chemical attributes are reasonably homogeneous. The value or suitability of a habitat for selected animal species is characterized numerically by an interagency team estimating the degree to which life requisites are provided.

The HEP Procedures specify how weighting and scaling methods are to be applied to an interagency team's measurements of life requisites on a per unit area basis to develop habitat suitability index values for a habitat. The habitat suitability index, multiplied by area, provides the "Habitat Unit" used to measure habitat value. Predicted changes in the habitat units for an area with relatively uniform habitat provide measures of the impact of a project, an ownership change, and/or a new management regime.

The monetary evaluation procedures in the draft HEP Procedures will be superseded by the recreation valuation procedures in the Manual and, therefore, are not analyzed in this paper. The draft HEP Procedures address the important problems of out-of-kind mitigation-compensation, but they do not adequately discuss how values for different habitats are to be determined and used to justify out-of-kind measures to mitigate-compensate project wildlife impacts. As a consequence, this paper cannot analyze the probable impact of the Procedures on out-of-kind mitigation-compensation problems.

WRC Manual

The purpose of the Manual is to provide procedures for the evaluation of beneficial and adverse effects of Federal and Federally-assisted water resource project in compliance with the Principles and Standards and other applicable economic evaluation requirements. For the evaluation of some types of benefits and costs, the Manual presents procedural guidance that is the same or very similar to current agency practice. For other types of benefits and costs, however, the Manual gives new or quite different guidance, and agency benefit-cost evaluations will be conducted differently in the future.

Three parts of the Manual will significantly affect agency evaluation of wildlife conservation measures to be included in alternative project plans. The recreation benefits chapter presents guidance on the use of three acceptable methods for estimating the economic value of recreation activities with and without alternative projects. Agencies in the past have typically used the unit-day value method, which the Manual will constrain to small projects, and have not adequately estimated recreation benefits at substitute sites or in the without-project condition. Application of the approved travel cost and contingent valuation methods to large projects will generate benefit estimates based on relatively sophisticated economic analyses and empirical investigations. Net total recreation benefits will increase substantially for some projects and decrease for others, while recreation benefits incidental to wildlife conservation measures will be the same or increase.

One subsection in the chapter on NED costs addresses mitigation of wildlife and other losses resulting from alternative project plans. The subsection emphasizes that to the extent that such losses can be evaluated economically, mitigation is the substitution of one opportunity cost for another and, therefore, mitigation measures can increase the net benefits of a project where the marginal mitigation cost for each loss prevented (or compensated for) is less than or equal to the marginal opportunity cost of the loss. The Manual further requires that, if losses can be valued, the value of uncompensated losses remaining after mitigation shall be included in total project costs. This provision is consistent with the proposed FWCA Rules.

The Manual also includes guidance for the evaluation of risk and uncertainty in project plans. Various approaches are outlined that can be used to evaluate the risk and uncertainty involved in alternative mitigation plans. Neither the HEP Procedures nor the wildlife resource management literature provide unique or ideal valuations of habitat, project impacts, or the productivity of alternative management regimes. Application of the Manual guidance, however, could inform decisionmakers of the types of risks and uncertainty that planners believe will affect project mitigation plans, the adjustment in mitigation plans that might be made to adapt to the effects of risk and uncertainty, and the gains and losses of various types that might accrue from these various adjustments in mitigation plans. Limitations of space preclude analysis here of the implications of introducing considerations of risk and uncertainty into mitigation planning.

ANALYSIS

Analytical Framework

The framework for the analysis is consistent with the FWCA Rules and derives from the WRC's P&S and the fundamental model of choice. The P&S requires that the significant impacts of a project (or other proposed action) be measured and the results be displayed in terms of four accounts: National Economic Development (NED), Environmental Quality (EQ), Social Well-Being (SWB), and Regional Development (RD). The fundamental model of choice characterizes problems in terms of the two basic elements of any act of choice: the alternatives available to the decisionmaker, and his preferences among alternatives.

The analysis focuses on trade-offs between aggregate measurements appropriate to the NED and EQ accounts of the impacts of alternative project plans. Aggregate measures of project NED and EQ impacts are used to simplify the analysis and permit depiction of results with two-dimensional graphs. The concepts can be extended to many variables, and the graphic representations to mathematical formulations incorporating many dimensions.

The first step in the analysis is to describe the impacts (consequences) of the alternative plans for a project in a fashion appropriate under the FWCA Rules. The plans are assumed to have different net NED benefits and net fish and wildlife resource (EQ) consequences. Net NED benefits are measured in dollars; net fish and wildlife consequences are measured in habitat units; and EQ other than fish and wildlife, as well as SWB and RD, impacts of the project are treated as identical under all plans.

The net impacts of alternative project plans are plotted as P&S possibility frontiers AF and GK in Figure 1. (These frontiers should be viewed initially with reference to origin O; origins O' and O" become relevant later in the paper.) Frontier AF depicts the impacts of the dominant, or efficient, alternative plans for a typical Federal project when evaluated under current agency procedures. Frontier GK shows the dominant (efficient) plans for the same project when evaluated by procedures in the new Manual and in compliance with the FWCA Rules.

Other things equal, increases in NED and fish and wildlife habitat are clearly desired by society. This means that any plan with impacts lying due north, northeast, or due east of another plan in Figure 1 is superior to it, and the former plan may be said to dominate the latter. A plan is called efficient if, given the alternative plans available, it is impossible to obtain more of one desired project impact without giving up some of one or more other desired impacts. Dominated plans can therefore never be efficient, and all plans on a P&S possibility frontier are efficient and dominate those plans with impacts below and/or left of the frontier.

The P&S possibility frontiers AF and GK in Figure 1 are drawn as smooth continuous curves on the assumption that one or more elements in any basic plan can be varied in scale. In practice, of course, the frontier for a project could have kinks, steps, or discontinuities. The analysis here is easily extended to cover irregular frontiers.

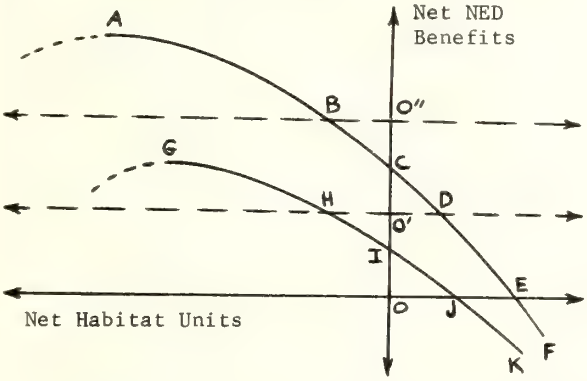
Effects on Alternatives Available

Evaluation of the typical Federal water resource project under the Manual and FWCA Rules instead of under current agency procedures will shift the efficient set of project plans from the P&S possibility frontier AF to GK in Figure 1. The reasons for the shift are as follows.

First, the Manual and FWCA Rules require previously neglected costs to be estimated and included in total project costs. Second, the Manual requires agencies to use valuation methods superior to their present methods, and this will reduce previously overstated project benefits. As a consequence, except for projects where recreation benefits are important, the net NED benefits and P&S possibility frontier of the typical Federal project will be lower when evaluated under the Manual than under present agency procedures. For these reasons frontier GK lies entirely below AF.

A P&S possibility frontier estimated using the Manual will also be parallel or less steeply sloped than one based on present agency evaluation practices. Recreation benefits incidental to the wildlife conservation measures included in the project will be the same or larger when evaluated under the Manual. Where the marginal recreational benefits incidental to mitigation measures are the same, the net NED benefits foregone to mitigate project-related damage to wildlife habitat and, therefore, the slope of the frontier will remain unchanged. However, where the marginal recreation benefits of of mitigation actions are larger, the net NED benefits foregone to mitigate project-related habitat damages and the slope of the P&S possibility frontier will be less when evaluated under the Manual than under current agency procedures. Frontier GK in Figure 1 is drawn less steeply sloped than AF because it represents the effect expected for the typical Federal project.

Figure 1



Further, the Manual will reduce the habitat damages expected to be associated with the NED-maximizing plan for the typical project. The Manual directs planners to investigate the substitution of one opportunity cost (in this instance the costs of mitigation actions) for another (the costs associated with NED benefits foregone by habitat damage). Where the marginal mitigation cost for each loss prevented is less than the marginal uncompensated opportunity costs, measures that prevent such losses increase project net NED benefits and simultaneously reduce its total damage to wildlife habitat. Therefore, point G on frontier GK lies southeast of point A on AF in Figure 1 because the NED-maximizing plan for the typical Federal project is expected to include more mitigation measures when evaluated under the Manual than under current agency practices.

To this point the analysis has assumed that the downward shift in the P&S possibility frontier and reduction in the choice set that result from implementation of the Manual and FWCA Rules will not introduce any discontinuity in the frontier and choice set for a project. The assumption of continuity, however, may or may not be accurate for a particular project.

The P&S possibility frontier for a project evaluated under either current agency or new Manual procedures could pass through the third quadrant in Figure 1. Alternative plans with third quadrant outcomes "solve" the water resource problem under investigation, but do so with negative NED and EQ consequences and, therefore, are dominated by the no project alternative represented by the origins O, O' and O" in Figure 1. As a consequence, notwithstanding the fact that alternative plans may have elements that can be varied in scale, the P&S possibility frontier and choice set for a project may become discontinuous, or develop some new discontinuity. The following table indicates the shifts in P&S possibility frontiers depicted in Figure 1.

Origin in Figure 1	Current Procedures	New Manual & FWCA Rules
O	AF	GK
O'	AF	GHO'IK
O"	ABO"CF	O"IK

Discontinuity in the P&S possibility frontier associated with origins O' and O" can simplify, complicate, or do away with choice among alternative project plans, for then agencies must choose among the quite disparate alternatives of (a) plans with net NED benefits and EQ losses, (b) no project, and/or (c) plans with EQ gains and negative net NED benefits, or select the no project alternative. Although discreteness among alternatives is sometimes helpful in decisionmaking, it may or may not be helpful where the alternative plans differ very substantially in their NED and EQ impacts. Whether the discrete choices created by the Manual and FWCA Rules will facilitate or hinder choice among the alternatives will depend on the particular circumstances surrounding the project and agency policy.

The impact of the Manual and FWCA Rules on the P&S frontier will further depend on whether or not projects are constrained to be economically justifiable and/or project related habitat losses must be fully compensated. The economic constraint would rule out the portion of the P&S frontier in the fourth quadrant of Figure 1, and the compensation constraint would exclude the portion in the second quadrant. The table on the next page shows the shifts in P&S frontiers in Figure 1 where projects are evaluated under the Manual and FWCA Rules and economic and/or compensation constraints are imposed. Evaluation in the presence of these constraints reduces the relevant choice set, introduces discontinuities, and increases the probability that the no project alternative must or will be the selected alternative. Of course, these constraints necessarily vitiate the intent of the P&S to have agencies consider the full range of alternative plans in the selection of the recommended plan, as well as throughout the entire planning process.

Finally, the Manual will improve agency decisionmaking. Agencies in the past have selected plans on the basis of faulty information concerning the NED and EQ impacts of the alternatives available. Poor evaluation methods and procedures have led agencies to recommend plans they believed to be on the P&S possibility frontiers AF or ABO"CF in Figure 1 where, in fact, the plans were on or below the frontiers GK, G(HI)K, or (GI)K, the origins for these frontiers being O, O' and O", respectively. The total cost of these mistakes to the Nation is unknown. Although limitations of space preclude consideration here of the imperfections of the Manual, the evaluation procedures that it presents may be expected to reduce agency errors attributable to flawed procedures. Of course, errors due to agency bias and scientific, technical, and prediction errors will remain.

Constraint	Origin in Figure 1	Current Procedures	New Manual
Economic	O	AE	GJ
	O'	AD	GHO'
	O"	ABO"	O"
Compensation	O	CF	IK
	O'	CF	O'IK
	O"	O"CF	O"IK
Economic & Compensation	O	CE	IJ
	O'	CD	O'
	O"	O"	O"

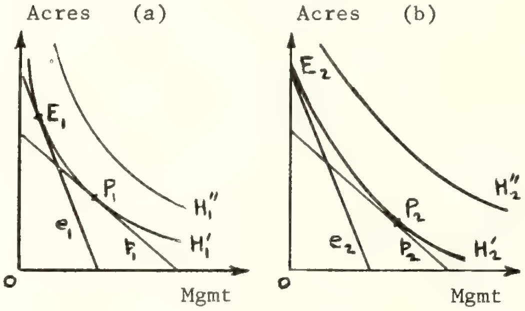
Effects on Acquisition-Management Choices

The FWCA Rules require Federal agencies to include in project plans such wildlife conservation measures as they find justifiable to maximize overall project benefits to the public. Mitigation and compensation measures must be undertaken at minimum cost if agencies are to select a plan on the project P&S possibility frontier. As a consequence of this requirement for efficiency, agencies must determine whether active management of wildlife areas, acquisition of wildlife areas, or a combination of management and acquisition will minimize the total costs of providing any specified increase in habitat units needed to mitigate or compensate project-related habitat damage.

Two cases may be distinguished: (1) the habitat suitability index in future years is predicted to be the same for an area (a) with acquisition and no management or (b) without acquisition; and (2) the habitat suitability index in the future is predicted to be greater (a) with acquisition and no management than (b) without acquisition. In the first case, the relative costs of land acquisition and management affect the proportion of expenditures allocated between acquisition and management, but acquisitions must be accompanied by active management if project costs (benefits) are to be minimized (maximized). In the second case, however, if the cost of acquisition relative to management is sufficiently low, acquisition without active management can be the cost-minimizing (benefit-maximizing) method to achieve the specified compensation goal. The analysis supporting these conclusions follows.

Active management uses resources, and hence involves costs, to increase the potential productivity of habitat (i.e., increase the habitat suitability index of the habitat) above what it would have been without management. In case (1) acquisition without management produces no increase in habitat suitability, only management can do so. Therefore, the isoquants in panel (a) of Figure 2 do not intersect the vertical axis because management is essential if potential habitat productivity is to increase. (The isoquants H_1' and H_1'' in Figure 2 indicate alternative combinations of land and management resources that can be employed efficiently to produce H' and H" units of improved habitat, where habitat is measured in habitat units, H, and H" is greater than H'.) In case (2), though, acquisition without management can increase habitat suitability, and therefore the isoquants in panel (b) of Figure 2 intersect the vertical axis. In case (2) management is not absolutely required to increase potential habitat productivity.

Figure 2



Lines e_i and p_i in Figure 2 are isocost (i.e., constant cost) curves that indicate the alternative combinations of land and management resources that can be purchased at two different sets of relative prices for land and management. (Lines parallel to e_i and p_i but not drawn in Figure 2, would represent attainable combinations with higher or lower total expenditures at given relative prices than the total expenditures represented by lines e_i and p_i.) Cost minimization requires the agency to select the combination of acquisition and management on the isoquant associated with the specified increase in total habitat units, say H_i' in Figure 2, on the lowest possible isocost lines.

Given the relative prices embedded in line p_i, cost minimization requires the selection of combinations P_1 and P_2 to obtain H_1' and H_2' habitat units; any other combination on curves H_1' would require the agency to operate on a higher isocost line than P_1. In both cases cost minimization requires acquisition and management. At the relative prices associated with lines e_i, however, minimization of total costs would require the selection of combinations E_1 and E_2, or in case (2) the agency would acquire land but not undertake active management. As a consequence, contrary to the section-by-section analysis published with the proposed FWCA Rules, acquisition without management can be consistent with the FWCA Rules requirement that conservation measures be selected to maximize overall benefits to the public and be justified using assessment and evaluation techniques reflecting wildlife habitat values (FWCA Rules, p. 29303).

Effects on Preferences and Selected Plans

The FWCA mandates that wildlife conservation receive equal consideration and be coordinated with other features of water resource development programs throughout agencies' planning and decisionmaking processes. One objective of the proposed FWCA Rules, of course, is to ensure that in fact Federal agencies will regard wildlife conservation as a programmatic and project purpose or goal equal to other project purposes or goals. Toward this end, the Rules require a construction agency to explain in detail, in terms of obtaining maximum overall project benefits, the reasons why it deems conservation measures recommended by wildlife agencies for compensation of wildlife resource losses are not justifiable.

Most interpreters of the Rules believe that by requiring (a) equal consideration for wildlife resources and (b) justification of rejected compensation measures agencies will select project plans with less wildlife damages, or reject all plans and select the no project alternative, than under current decisionmaking procedures. In fact, however, simultaneous implementation of the Manual and Rules can lead to a third outcome not commonly recognized by advocates of the Manual and Rules. This outcome is the selection of a plan with smaller net NED benefits and larger wildlife resource damages than would occur under current agency decisionmaking procedures. The analysis to support this conclusion follows.

The basic tools in the analysis are the P&S possibility frontiers developed above and alternative representations of decisionmaker preferences with properties consistent with the FWCA Rules. Preferences exhibiting properties consistent with the Rules are depicted in Figures 3 and 4 by indifference curve maps I_i and I_i'. These curves provide two-dimensional geometric description of preferences among alternative combinations of net NED benefits and wildlife habitat.

Figure 3

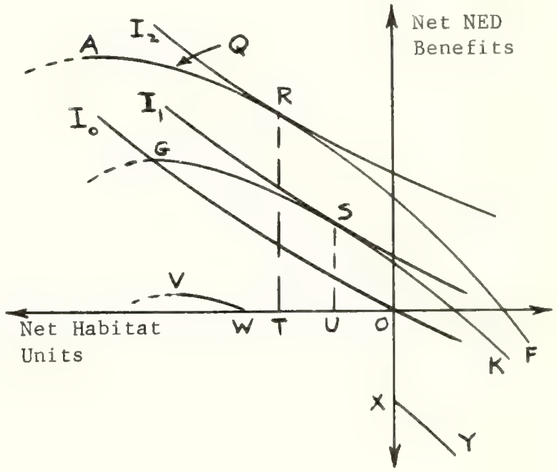
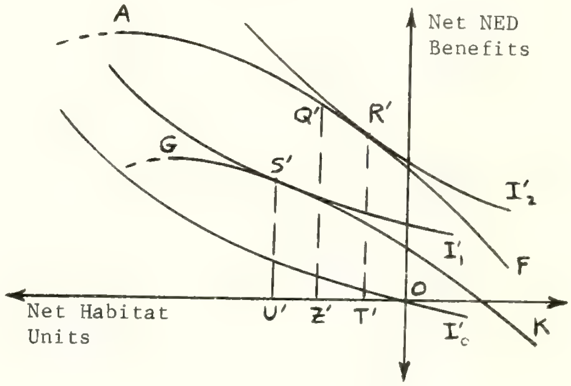


Figure 4



The properties of the indifference curve maps, their consistency with the Rules, and their analytical use are as follows. Combinations on the same curve are viewed as equally good (i.e., have the same overall benefits to the public), and therefore express willingness to trade net NED benefits for improvements (or less damages) in wildlife habitat. The shape of the curves reflects the assumption that the willingness to trade net NED benefits for improvements in wildlife habitat diminishes as NED benefits become smaller, and vice versa. Combinations on higher curves are preferred to all those that lie on lower curves (i.e., they have larger overall benefits to the public), and thereby reflect the positive evaluation of both net NED benefits and improvements in wildlife habitat envisioned in the FWCA Rules. Maximization of overall project benefits to the public would require the decisionmaker to select the plan on the project P&S possibility frontier that would be on the highest attainable indifference curve.

One feature of the indifference curve maps in Figures 3 and 4 deserves special comment. The curves have been drawn such that to maximize overall project benefits a decisionmaker would select the plan associated with point R in Figure 3 (point R' in Figure 4) instead of the plan associated with point Q (Q') on frontier AF, where Q (Q') is the point that would be selected under current agency decisionmaking procedures. That is, the curves are drawn in accordance with the expectation that, other things the same, the FWCA Rules requirement for (a) equal consideration of wildlife and other project features and (b) justification of the rejection of recommended compensation measures would lead to the selection of project plans with smaller net NED benefits and less wildlife habitat damage than characterize plans that would be selected under current procedures without the Rules.

The impact of simultaneous implementation of the FWCA Rules and the Manual can be shown with the aid of Figures 3 and 4, where curve AF is the P&S project possibility frontier evaluated under current agency procedures. GK and VWOXY are P&S possibility frontiers evaluated under the Manual, and I_i and I_i' are preference maps consistent with the requirements of the FWCA Rules. Figure 3 illustrates two of the three possible outcomes. Maximization of overall project benefits requires the agency either (1) to select the plan associated with point S where the relevant P&S frontier is GK, or (2) to reject all plans and select the no project alternative at point O where the relevant frontier is VWOXY. Figure 3, therefore, shows the impact of the Manual and Rules expected by most observers, namely, some projects acceptable under current agency procedures would not be undertaken and those that are constructed would have smaller net NED benefits and smaller wildlife habitat (environmental) damages.

Figure 4 shows the third possible outcome of simultaneous implementation of the Rules and the Manual: maximization of overall project benefits can lead an agency to select a plan that would have smaller net NED benefits but larger wildlife habitat (environmental) damages. In Figure 4, the plan associated with point S' on frontier GK is superior to the no project alternative and maximizes overall project benefits as defined by the preference map I_i'. In this case, the wildlife habitat damages would equal OU' habitat units, and U'Z' more damage would occur than would occur under current agency decisionmaking procedures. The reasons for this somewhat surprising result are that (1) the reduction in the choice set (i.e., downward shift of the P&S possibility frontier from AF to GK) is large relative to the reduction in the marginal cost of mitigation-compensation attributable to the Manual (i.e., reduced slope of frontier GK as compared to AF), and (2) the preference map in the relative net NED benefit-habitat unit space places a relatively high value on net NED benefits. (In the jargon of economic theory, the "income effect" attributable to the Manual is opposite in sign and exceeds in absolute value the "substitution effect" of the Manual.)

The conclusion is simply stated. Although implementation of the FWCA Rules would be expected, other things equal, to lead agencies to select project plans with smaller net NED benefits and less wildlife habitat damages, simultaneous implementation of the Manual will lead in some instances to the selection of project plans with smaller net NED benefits and more wildlife habitat damages than under current decisionmaking procedures.

SUMMARY OF FINDINGS

The Manual will constrain agency choices by reducing the net NED benefits of the typical project, reduce the marginal cost of some mitigation-compensation measures, increase the probability of discontinuities in the choices faced by agencies, and reduce evaluation errors attributable to flawed procedures. The FWCA Rules will often, but not always, require wildlife habitat acquisition and active management to achieve mitigation-compensation objectives, make unacceptable some projects that would be acceptable under current agency procedures, and reduce the net NED benefits and wildlife habitat damages of some, though not all, projects. Simultaneous implementation of the Manual and FWCA Rules would lead in some instances, however, to the selection of project plans with smaller net NED benefits and larger wildlife habitat damages than under current decisionmaking procedures. The impact of the Manual and Rules will be greatest, and the intent of the P&S vitiated, if projects are constrained to be economically justifiable and/or project-related habitat losses must be fully compensated.

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Promising Legal and Procedural Strategies for Reserving Instream Flows in Thirteen Western States [1]

Joseph M. Solomon[2] and Gerald C. Horak[3]

This paper identifies, describes, and evaluates the most promising strategies for reserving flows at existing and proposed projects. The strategies are designed to promote the bargaining process between Federal/State resource development and conservation interests.

Introduction

This discussion focuses on institutional bargaining strategies for reserving instream flows for fish and wildlife under existing Federal and State authority in thirteen western states. In 1976 the Western Energy and Land Use Team of the Office of Biological Services, U.S. Fish and Wildlife Service awarded a contract to Enviro Control, Inc. to conduct an investigative study of the potential utility of twenty-one such strategies. The strategies are designed to promote the bargaining process between Federal and State resource development and conservation interests. Selection of the twenty-one strategies was made from a larger set of strategies identified by Enviro Control and a law firm through a review of Federal and State laws, interstate compacts, and water quality laws (Dewsnup, et al. 1977). Our task was then to evaluate the most promising strategies in depth.

Investigations of the applicability and utility of the strategies were conducted through private communications with officials of each State's fish and game agency, attorney general offices, state water engineer offices, as well as reviewing State water laws and published documents. These investigations, also, included private communications with officials of the U.S. Fish and Wildlife Service (FWS), Federal construction agencies, and Federal permit and licensing agencies. The format followed for documenting the applicability and potential utility of each strategy included: identification of State and Federal Authority; general application of how the strategy might be implemented and the action required at various levels; illustration of the strategy's past utility in each State through the development of case studies; an evaluation of the strategy's past effectiveness and potential utility in recognition of financial costs, institutional constraints, probably benefits, and references. For each State a report (Nelson et al. 1978) was prepared discussing the twenty-one strategies.

The following matrix identifies those states which have successfully utilized the strategies. The strategies were rated as follows: 1-high utility and/or potential; 2-moderate utility and/or potential; 3-low utility and/or potential; N/A-not legislatively available to this State. The rating assigned to each strategy is based upon the evaluations provided by State and Federal Officials during the initial study. Based upon these ratings, we have selected four strategies which have achieved or can be expected to achieve the greatest effectiveness for reserving instream flows in recognition of existing institutional constraints.

The four strategies selected include: State Appropriation of Instream Flows, State Discretionary Water Permit Authority, Federal License and Permit Stipulations, State and Federal Flow Requests Made Early.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado July 16-20, 1979.

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Table 1--Evaluation Matrix

STRATEGIES	AZ	CA	CO	ID	MT	NV	NM	ND	OR	SD	UT	WA	WY
APPROPRIATIVE WATER RIGHTS													
State Condemnation/Reallocation of Water Rights	N/A	N/A	N/A	3	3	N/A	N/A	3	3	3	N/A	3	N/A
State Appropriation of Instream Flows	3	N/A	1	1	3	N/A	N/A	2	2	2	N/A	1	3
State Maratoria on New Appropriations	N/A	N/A	N/A	3	3	N/A	N/A	3	3	2	3	2	N/A
State Discretionary Water Permit Authority	3	1	N/A	2	2	2	3	3	1	2	3	1	3
LEGISLATIVE/ADMINISTRATIVE CONTROLS													
Federal Reauthorization of Projects	2	2	3	3	3	3	3	3	2	3	3	2	2
State-Federal Wild and Scenic Rivers Systems	3	2	2	1	2	3	3	3	2	2	2	2	2
State Definition of Navigable Waters	N/A	3	N/A	3	N/A	N/A	N/A	N/A	3	N/A	N/A	N/A	N/A
State-Federal Interagency Consultation	3	3	3	3	3	3	3	3	3	3	3	3	3
Federal License and Permit Stipulations	3	1	1	2	2	3	3	2	1	2	3	2	2
State Allocation of Reservoir Space	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
State Purchase and Lease of Water Rights	2	3	1	3	2	3	3	3	2	2	2	2	3
WATER RESOURCE PLANNING													
Federal WRC Planning Programs	3	3	2	2	3	3	2	3	3	2	2	2	3
Federal Aid Funding to Purchase Storage	2	3	1	2	3	3	3	3	2	3	2	3	3
Federal Reservoir Construction/Enlargement	3	3	3	2	3	3	3	3	3	3	3	2	3
WATER RESOURCE MANAGEMENT													
State Water Rights Records Analyzed	2	3	2	3	3	3	2	3	2	2	2	2	3
State-Federal Flow Requests Made Early	2	1	1	1	1	2	2	2	1	2	2	1	1
State-Federal Flow Requests Made Specific	2	2	2	3	2	2	3	3	1	3	3	2	3
State-Federal Combined Storage/Flow Requests	3	3	2	2	3	3	3	2	2	2	2	2	3
ENGINEERING ALTERNATIVES													
Coordinated Multireservoir Operations	3	1	3	2	3	2	3	2	1	2	2	2	3
Reservoir Sediment Storage Releases	3	3	2	3	3	3	3	2	3	3	3	3	3
Stream Channels to Convey Stored Water	2	3	3	3	3	3	2	3	3	3	3	2	2

1-high utility and/or potential
2-moderate utility and/or potential
3-low utility and/or potential
N/A-not applicable to this State

State Appropriation of Instream Flow

Within the category of Appropriative Rights to strategies have been applied frequently and/o hold considerable promise for the States of Clifornia, Colorado, Idaho, Oregon, and Washigton. These States have enabling legislation fr (1) State Appropriation of Instream Flows, (xcept California) and (2) State Discretionary Wter Permit Authority (except Colorado). Where aailable, State Appropriation of Instream Flows gves the State legal standing for ensuring that is water claim will be applied to the benefit of fsh and wildlife. The major weakness of this srategy is defending against legal challenges cntesting the quantity of streamflow appropriaed or reserved by the State is in excess of tat amount necessary to meet fish and wildlife neds. Refinements, however, in instream flow mthodologies can be expected to strengthen the Sate's defense against legal challenges. The csts in manpower and funds needed to quantify istream flows generally are substantial which ncessitates a determination of the potential bnefits vis-a-vis the costs-benefits of other aency program activities.

In Colorado (Nelson, et al. 1978c) the Division of Wildlife must recommend to the State Water Conservation Board that it file for the requested instream flows, as set forth by Senate Bill 97. Although, instream flow appropriations have been made since its passage in 1973 the constitutionality of Senate Bill 97 was recently challenged in the State Supreme Court. Final arguments were made before the court in April 1979 with subsequent adjudication in May 1979 in favor of Senate Bill 97 (Colorado R. Water Conservation District and Southwestern Colorado Water Conservation District v. The Colorado Water Conservation Board No. 28407, 1 May 1979). This decision should significantly enhance the Division of Wildlife's efforts to reserve minimum flows for fish and wildlife.

In Colorado water right priorities are established when an appropriator's water claim filed with the Water Division Court is adjudicated. The appropriation date, court decree date, and the adjudication date are all necessary for establishing the priority of the claim. Since 1973 the Division of Wildlife through its recommendations to the State Water Conservation Board has received 40 decrees, 467 approvals from the Board but no decree dates, and 100 recommendations are still before the Board. Since 1974 the Division of Wildlife has spent between $80,000 to $100,000 per year in performing the necessary stream flow studies to support their recommendations.[4]

Under Idaho Water Code Sections 42-1503 and 42-1504, as adopted by the Legislature 17 March 1978, the Idaho Department of Fish and Game, other State and local government agencies, and private organizations must submit a written request with the Water Resource Board that it files with the Director of the Department of Water Resources for appropriation of instream flows. Applications approved by the Director must be submitted to the Legislature. A water right is established if the Legislature either approves or takes no action on the recommendation. As of June 1979 the Department of Fish and Game has submitted thirteen requests. While only two have been approved by the Director of the Department of Water Resources, the remainder are in various stages of review by the Board of Water Resources and the Director of the Department of Water Resources. The two approved requests will be placed before the Legislature in its next session, January 1980. Although this is a lengthy process, the Department of Fish and Game is not particularly concerned since an appropriation date is established when the request is submitted to the Board of Water Resources.[5]

Washington has two statutes which provide mechanisms for reserving instream flows. The Minimum Water Flows and Levels Act (Rev. Code Wash. 90.22) and the Water Resources Act of 1971 (Rev. Code Wash. 90.54). As viewed by officials of the Department of Fisheries and Department of Game, the Water Resources Act has been the most widely utilized and effective law for securing minimum instream flows. These officials consider the Minimum Water Flows and Levels Act to be too time-consuming and cumbersome for extensive use (Nelson, et al. 1978 1). Under the Water Resources Act base flows are set by administrative regulation. The base flow is a "ball park figure" arrived at by combining data on historical flows in a given stream reach with estimates of the environmental value of that stream. Defining a base flow involves a number of steps primarily conducted in a process termed "Stream System Analysis."

State Discretionary Water Permit Authority

This strategy is available to each of the thirteen States, except Colorado (Nelson, et al. 1978). Under this strategy, the State fish and game agency or private group can petition or recommend to the State water rights administrator (State Engineer) that applications filed for new, exchanged, or transferred water rights be denied or modified when either they jeopardize existing appropriations/reservations granted for the benefit of fish and wildlife or that new permits be modified or denied as a matter of the "public interest." Each State has a statutory clause empowering the water rights administrator to deny permit applications which are contrary to the "public interest." This strategy is most effective when applied in States (Idaho, Oregon, Washington) which allow the appropriation or reservation of instream flows for fish and wildlife. In these States, the water rights administrator generally will deny or modify permits which threaten prior appropriations or reservations made for fish and wildlife.

Federal License and Permit Stipulations

Although available to all States under Federal authority, broad application or recent recognition by Federal and State fish and wildlife agencies of Federal License and Permit Stipulations is most prevalent in California, Colorado, and Oregon (Nelson et al. 1978 b,c,i). In Idaho and Washington (Nelson et al. 1978 d,1) this strategy has been utilized to a moderate extent. The Bureau of Land Management (BLM), the U.S. Forest Service (FS), and the Federal Energy Regulatory Commission (FERC), issue permits and licenses for resource development, allowing fish and wildlife interests an opportunity to recommen instream flows. The legal basis for this strateg in relation to the FS and the BLM controlled land derives from the Federal Land Policy and Management Act of 1976 (P.L. 94-579). The legal basis with regard to the FERC derives from its regulatory authority over the non-Federal hydroelectric industry. As a quasi-judicial commission of the Department of Energy, it licenses construction, operation, and maintenance of dam and reservoir projects utilizing waters and lands of the United States under the mandates of the Federal Power Act of 1920 and other Federal laws.

In connection with the Forest Service or BLM permit process, the costs associated with this strategy are limited to those incurred during preparation of the fish and wildlife input to the impact survey. The magnitude of the instream flow study and time associated with preparing the report submitted to the permit agency as part of this input would be the principal cost determinants.

For FERC-licensed projects, the costs linked with this strategy are directly dependent on the extent of agreement between the fish and wildlife interests and the applicant. Expenditures of time and money increase as negotiations advance through the informal meeting stage to the FERC hearing stage. As specified by the Federal Power Act fish and wildlife studies are funded by the utility company applicant.

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[4] Rex Taliaferro. 1979. Ecol. Serv., Colo. Div. Wild. Denver Colo., Private Communication.

[5] Stacy Gibhart. 1979. Bureau of Fish. Id. Dept. Fish and Game, Boise Id. Private Communication.

State and Federal Flow Requests Made Early

This strategy has received the widest use among all States. Offering timely flow recommendations requires that State and Federal fish and game agencies become involved in the planning process when Federal agencies plan the construction of dams and reservoirs. Recommendations that are timely, i.e. made prior to project construction, have a greater chance of acceptance and implementation than those made during or after construction (Nelson,et al. 1976). The legal basis of this strategy is the Fish and Wildlife Coordination Act of 1958 and the planning procedures adopted by the Federal construction agencies. In fact, during the 1974 and 1978 Congressional Hearing on the administration of the Coordination Act the point was repeatedly made that fish and wildlife interests have not requested measures early enough.

This strategy is applicable when any Federal construction agency is planning a reservoir, particularly in the earlier phases of planning before design and cost options are foreclosed. Also, this strategy would apply when the Federal Energy Regulatory Commission is considering licensing or relicensing a dam and reservoir project, or when the Bureau of Land Management or Forest Service is in the process of issuing a permit to construct a dam on Federal lands.

To apply the strategy, the State fish and game agencies and FWS must conduct timely investigations to formulate instream flow recommendations. Application of the strategy is contingent upon prompt notification by the construction agencies of the initiation of project planning. Each construction agency has promulgated procedures to provide for early notification and cooperation with the FWS and the State fish and game agency. Once the Federal and state fish and game agencies have been notified of a project plan and brought into the planning process, they must initiate an investigation to develop timely recommendations. The proposal rules to administer the Fish and Wildlife Coordination published 18 May 1979 in the Federal Register will facilitate early consultation and reporting.

Conclusion

Strategies to reserve instream flows have been utilized in varying degress in the thirteen western states, and the potential utilization of these strategies also varies state-to-state. The recent court decision in Colorado offers optimism to fish and wildlife interests; whereas, the court decision in California dismays them. The outlook is unclear.

The strategies we reviewed are by no means a panacea. However, we encourage State and Federal administrators of fish and game agencies as well as conservation organizations and private individuals to thoroughly examine these strategies, determine where and when selected strategies can be employed to protect and preserve fish and wildlife population and habitats. Recent actions by the Executive Branch, Congress, and various States to more equally consider fish and wildlife values promotes the application of these strategies.

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Mitigation — Is It the Answer? [1]

Dale E. Whitesell[2]

If America's landowners are to continue paying the price to preserve habitat; environmenta, recreational, tax, and other land conservation incentives must not be eroded by arbitrary governmental intervention. It's especially important, in terms of waterfowl conservation, that landowner, developer, and the government work together to salvage wetlands whenever possible. Half a marsh is better than none. It's the only kind of mitigation waterfowl will ever benefit from.

Wildlife habitat exists because either nature or man has allowed it to. Creation still rests firmly in the grip of nature, however, perpetuation of any wildlife species today is almost totally dependent on the habitat management efforts of man. Incentives for preserving or destroying wildlife habitat most often originate from the state and federal government levels, eventually permeating the private sector marketplace. If any land ethic is to survive the long haul, it must embrace the esthetic, ecological and economic values held by America's landowners. The term "mitigation" would soon become academic if these fundamental incentives for keeping wildlife habitat intact were ignored.

Webster's definition of mitigation is: "to cause to become less harsh or hostile." However it is defined, it is still only a word to wildlife. And while it may be possible to mitigate civilization's impact on upland habitat, as evidenced by the Soil Bank Incentives program of the '50's and early '60's, no way yet has been found to mitigate the loss of wetland environments.

Wetland habitat is special. Healthy wetlands balance out the ever-changing water cycles that influence the hydrology of an area. They act as sponges during wet years, drinking in floodwaters and retarding destructive runoff. As such, they are buffers against the damaging effects of erosion and siltation, preventing soil loss and catching silt before it clogs waterways. It has been estimated that floods cost society approximately $3.8 billion annually, not including the loss of life. Had man recognized sooner the intrinsic value of the wetlands he destroyed, this costly toll might have been averted.

During inevitable periods of drough wetlands have the opposite effect on the environment by releasing their waters to benefit both wild and domestic life. We lands also recharge aquifers and groundwater supplies. Their waters trap air pollutants such as sulfates and water pollutants such as nitrates which in tur are decomposed by microorganisms found there.

Quality wetlands are living filters that help cleanse and purify the very ai and water we consume. Environmental economists estimate that in terms of ber fitting man, every acre of wetland is wc from $50,000 to $80,000. In other words it would cost man at least $50,000 per acre to replace all the functions of a balanced wetland. In essence, wetlands mitigate the harsh excesses of nature. They are a source of natural mitigation that no man-made contrivance can yet duplicate. Considering what can be lost when a wetland is destroyed, can any mitigation, however well conceived, really be the answer? In terms of environment and North American waterfowl propagation, I think not. Until we can sit down and talk with the ducks about all the environmental subtleties needed to ensure their survival, man's wetland mitigation efforts can be likened to a smoker who wants to alleviate the noxious effects of cigarettes by changing to a low-tar brand. The real solution would have been not to start smoking in the first place. The old adage about an ounce of prevention being worth a pound of cure certainly holds true in the case of wetland habitat conservation. It would pay us well not to compromise our wetlands over an intellectual alternative called "mitigation."

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[1] Presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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Aside from the many agricultural, commercial and municipal benefits derived from wetlands, another important incentive for keeping them intact is waterfowl hunting. In the 14-state Mississippi Flyway region alone, more than 5,000 private waterfowling clubs control and manage a minimum of 2.5 million acres of wetland habitat. This is prime wetland habitat. In order to attract waterfowl, it has to be. But its desirability is not limited only to ducks -- hundreds of other species of wildlife find haven there as well. The federal government today, through its hunter-paid-for Duck Stamps, has managed to acquire but not develop only 1.7 million wetland acres throughout the entire United States. This is a mere fraction of the wetland acreage held by the private sector.

Many hunting clubs spend upwards of $50,000 annually to maintain and manage wetlands that are used by the hunter less than two months out of the year. Recently, an incentive-destroying move by the Internal Revenue Service threatened to remove the tax-deductibility of those clubs using wetlands for hunting purposes. Faced with continual and escalating maintenance costs, a significant number of club owners simply could not afford to pay the price of such government intervention. As a consequence, many of these crucial wetlands were destined to be cashed in for development. According to the Interior Department, from 200,000 to 300,000 acres of wetlands are already being destroyed in the U.S. every year. No amount of mitigation will ever compensate for their loss. Nearly half of America's original 127 million acres of wetlands have been drained since the turn of the century. As the demands of modern civilization accelerate, wetland destruction will increase proportionately unless incentives are pursued to encourage landowners to conserve them.

There is an even more insidious meddling taking place at the federal judicial level involving the hunting incentive. A consortium of ecologically ignorant anti-hunting groups is using the courts to handcuff funds earmarked for habitat (much of it wetland) development and management across the U.S. A recent suit charged that Pittman-Robertson funds (self-imposed tax on the sportsman) were in violation of the National Environmental Protection Act and therefore environmental impact statements should be compiled by the U.S. Fish & Wildlife Service before these funds can be allotted to the various states. Not only is such a debacle a slap in the face to the professional wildlife manager, but it also holds potentially disastrous consequences for the wildlife resource itself. Wildlife conservation, like any worthwhile endeavor, is simply a matter of economics. Without proper funding, the necessary management techniques that make habitat viable are stripped away and with them, the wildlife.

Before any meaningful strategy for saving America's wetlands can be made, the economic incentives of the private sector must be given priority. Of the estimated 74,400,000 wetland acres remaining in the U.S., over 63,000,000 are under private tenure, with federal and state ownership totaling a little over 11,000,000 acres. It is the private sector, then, that will determine the destiny of America's surviving wetlands.

There is another decision pending in the Federal Court of Hawaii that could have serious ramifications concerning the landowners' incentive for maintaining wetlands. Because many wetland owners have channeled into navigable waterways to stabilize water levels on their marshes, a plaintiff in Hawaii is contesting that he should be given the right to navigate these private water lanes without penalty. Should the federal judiciary decide in his favor, another nail will have been nailed in the private wetland manager's coffin. Few landowners who have spent the time and expense to create, maintain and manage estuarial and other wetland areas, will ever permit their private land to become a public vehicle. Consequently such areas will cease to be sanctuary for the waterfowl as well as the complex community of life that is a wetland. Whenever the sanctity of the individual wetland owner is violated by myopic tax laws, ill-conceived governmental policies, whimsical legal judgments and the like, the incentives for preserving wetlands, and ultimately the wetlands themselves, will perish. If such federal bureaus as the IRS, OSHA and even the judiciary continue to create an atmosphere of stifling regulations that force upland and wetland owners to sacrifice their land to make ends meet, wildlife will inevitably be sacrificed as well.

Conceived in response to this nation's ecological consciousness, the Environmental Impact Statement, as it is applied today, may be more of a deterrent to sound land use policy than an incentive. If the Impact Statements meted out are to be of any consequence, in terms of wetlands preservation, they must be directed to every segment of society tampering with this resource. An isolated industry project here, or an Army Corps dam there, whose long-term impact should justifiably be monitored, in no way competes with the extensive depletion of wetlands by one faction totally immune from such governmental sanctions--agriculture. It is environmental folly on the one hand to take token reprisals against the occasional wetland destroyer while on the other, no attempt is made to curtail the habitual abuser. Considering this inequity, just how necessary is the Environmental Impact Statement?

Habitat conservation is costly. Under the free enterprise system it is an economic fact of life. If America' landowners are to continue paying the price to maintain and manage environments for wildlife, tax, recreational and other land-preserving incentives must not be eroded away by arbitrary governmental edicts. Since wetlands cannot be successfully mitigated, it is especially important that landowner, developer and the various governments work together to salvage them whenever possible. Half a marsh, afterall, is better than none. It is the only kind of mitigation waterfowl and the wetlands will ever benefit from.

Habitat Enhancement for Colorado Squawfish in the Yampa River in Conjunction with Railroad Construction[1]

James A. Sinning[2] and John W. Andrew[3]

The impact assessment for Colowyo Coal Company's Yampa River railroad spur determined that no adverse impact to the Colorado squawfish would result from construction and adverse impact was only a remote possibility as a result of operation. Colowyo Coal Company, in consultation with ERT/Ecology Consultants, Inc. and Water and Environmental Consultants, Inc., decided to construct additional backwater habitat suitable for rearing Colorado squawfish in two locations during railroad construction as a habitat enhancement feature. This paper discusses the design criteria and rationale for the backwaters, proposed use, interactions with state and federal agencies and some of the problems arising from this habitat enhancement project.

Historically, Colorado squawfish ranged throughout the "large river" habitat in the Colorado River basin including the Yampa River to near Craig, Colorado. During this century, various changes in habitat have reduced both the range and numbers of Colorado squawfish, in areas where it is still found, to the point that the species is designated as endangered by the U.S. Fish and Wildlife Service. Some of the possible reasons for the decline of this species are water diversion and dam construction which have modified physical habitat and temperatures, and the introduction of exotic species which may either compete with or prey on larval squawfish.

One notable change in habitat has resulted from water withdrawals and dam construction. During low summer flows, water withdrawals have significantly reduced flows in uncontrolled streams. Where streams are controlled, irrigation releases during summer low flows have mitigated the withdrawals in some stream reaches, but the impoundment of high spring flows has prevented much of the sediment flushing that occurred before stream controls were installed. The result on both controlled and uncontrolled streams has been a reduction in shallow areas with little current during the squawfish larval rearing period. While the extent of rearing habitat reduction has not been quantified, it has obviously occurred.

When the Colowyo Coal Company began development of their mine between Craig and Meeker, Colorado, studies revealed that the most economical and environmentally sound method of coal transport was by rail. This required construction of a rail spur from Craig, down the Yampa River, and up Milk Creek to the mine loadout. Environmental studies revealed that only insignificant impacts would result to the Yampa River from rail spur construction and operation, but the coal company offered to construct two backwater areas on the Yampa River in conjunction with the rail spur as a habitat enhancement feature. Since the morphology of these backwaters would be controlled, experimental rearing of hatchery-produced squawfish larvae would be facilitated, and interactions with exotic species could be studied.

There are really two phases to the design of such backwater areas. The design must consider the biological requirements for the intended use, and the physical/economic aspects of the design must be practical. From a biological standpoint, such a backwater design cannot be done with absolute certainty for the Colorado squawfish because the rearing habitat requirements are incompletely known. Since squawfish larvae have been found in relatively shallow backwaters which are largely dry during late fall and winter low flows, it was decided to try and duplicate these parameters in the artificial backwaters.

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Natural backwaters in which squawfish have been found are usually open to the main channel sufficiently that a small water circulation (from percolation at the upstream end) prevents stagnation. While they may have somewhat irregular bottom profiles, it was felt desirable to construct the artificial backwaters with a sufficiently regular, U-shaped profile to allow easy use of management techniques such as seining or block netting the open end of the channel. Since natural backwater formation processes could not be duplicated, percolation of water through the upstream end was designed into the upstream-end dam between the main channel and the backwater.

Another aspect of the backwater design was that they should be easily removeable if they proved unuseable for squawfish rearing either because of de facto operational characteristics or because they encouraged the proliferation of exotic competitive species such as redside shiners. This can be accomplished, based on the premise that the dams could be physically breached with relatively little effort and equipment by allowing natural sedimentation processes to return the backwater to a close approximation of its original condition.

Since the possibility of constructing backwater habitat enhancement areas was recognized relatively early in the railroad design phase (just after route selection), incorporating the backwater designs into the overall design was not a difficult task. Potential sites were chosen from stereo pairs of aerial photos. The choice criteria were the presence, configuration, and size of presently non-flowing side channels. These areas were chosen so that construction activity (and thus ecological disturbance) could be minimized. Another advantage of choosing old side channels was that since flow at one time created the channels, redirection of in-channel flows would be less, and backwater stability would likely be enhanced. Sediment data and river bed profiles were obtained during a field visit at which time the two best locations for backwater development were chosen based on professional judgement. At each location, four profile transects were measured across the main and side channels.

Geomorphic changes in the channel were determined, based on sediment load and size distribution and channel geometry, for the mean annual hydrograph and the 1 in 25 year flood hydrograph. The model used provided one-dimensional sediment routing, uncoupled from water routing, for each requested discharge. The model was operated with both natural (existing) conditions and with the porous dams in place, and the results with and without the dams were compared.

The maximum change in water surface elevation with the dams in place was less than one foot for the 1 in 25 year discharge of 15,250 cubic feet per second. The change in channel geometry (deepening) as a result of the backwater dams was also less than one foot. The model also indicated that water surface elevations during the average annual peak flow of 7100 cubic feet per second would be about two feet over the top of the upstream dam. Since the dam construction was specified of material of sufficient size, this overtopping would not cause loss of the dam. Because the adjacent land area (islands) forming the backwater are also overtopped during these peak flows, raising the dam height would not prevent annual peak flows from entering the backwater area. By allowing the peak flow to pass over the backwater dam and through the backwater, some sediment transport will occur through the backwater and more natural conditions will result. The downstream dam will not be overtopped by the average peak flow, but a flow of 1 in 25 years will overtop the dam. Thus during most years, sediment deposition at the lower end of the backwater is likely. This indicated that more maintenance would be likely at the downstream backwater area.

Based on the predicted water surface elevations, some erosion potential of the islands at the ends of the dams was predicted, and riprap protection was recommended. Bar formation and some channel agradation within the backwater areas was also predicted to occur during the descending limb of the annual hydrograph. This is expected to be primarily at the downstream end of the backwater area and will require periodic (though not necessarily annual) maintenance. Maintenance can be accomplished with small size earth moving equipment during low flows and is not likely to result in significant disturbance to the ecology of the area.

As is usual for new mine construction and operation, a variety of permits and approvals are necessary. The agency with primary approval responsibility for railroad construction was the BLM. Since bridge construction and channel encroachment of navigable waters were involved in the construction of the railroad, a Corps of Engineers 404 permit was also required. These approvals also involve the U.S. Fish and Wildlife Service which was charged with determination of impacts to endangered species (Colorado squawfish). Approval from the endangered species branch of the Colorado Division of Wildlife was also a requirement. Liaison with designated representatives of each governmental agency was initiated early in the project. Agency representatives were encouraged to be present throughout the field studies and were gathered in several formal meetings to verify unified approval of the entire railroad design including the backwaters. This procedure resulted in minimal friction and misunderstandings between all parties concerned, and it often provided ideas and insights for avoiding future problems which have plagued other mine and/or railroad construction projects.

In spite of careful planning some problems arose during construction of the backwaters. Projected locations of fill for the porous dams did not contain suitable size material after excavation, and the required size fill had to be transported from alternate locations of railroad cuts. In addition, fill size was not as uniform as desired, and it is expected that proper dam operation will not occur until the descending limb of the hydrograph. Unusually severe winter weather necessitated placing fill for one of the dams on ice. In addition, much of the fill was frozen into blocks. The result was that one dam was too porous when water first began to flow through it. This situation is expected to remedy itself by natural sediment deposition during the first year following construction as high water receeds. Because of lack of adequate rip rap at the dam ends coupled with abnormally high runoff, the upstream dam is rapidly eroding at the offshore end and will probably be breached. This will require repair and possibly the backwater channel morphology will have to be readjusted to regain the design shape and thalweg elevation.

Actual squawfish rearing is expected to be conducted by the Colorado Division of Wildlife. Because it was expected that backwater morphology would not be completely stable during the first year of existence, a decision was made early on to wait until the second year of backwater existence (1980 water year) before attempting squawfish rearing experiments. In view of the construction difficulties and abnormally high spring flows during 1979, this appears to have been a wise decision.

Once the porous dams have been properly stabilized and repaired (during 1979 low water), rearing experiments can begin. Because of the amicable relationship established between the coal company and government agencies and maintained throughout the period of construction, it is anticipated that a series of fruitful squawfish rearing experiments will result which would not have occurred had the rail spur not been constructed.

River Structure Modifications to Provide Habitat Diversity[1]

Thomas D. Burke[2]
John W. Robinson[3]

Abstract.--Discussion of beneficial and detrimental effects of Missouri River Bank Stabilization and Navigation Project and description of structure modifications used to improve fish and wildlife habitats, flood carrying capacity, and for controlling accretions. Methods include notched, rootless, and low elevation structures.

DESCRIPTION AND LOCATION OF THE MISSOURI RIVER

The headwaters of the Missouri River have their source along the eastern slopes of the Rocky Mountains in Montana, Wyoming, and Colorado. From its source, the Missouri extends 2,522 mi (4,058 km) to its confluence with the Mississippi. As illustrated in figure 1, the Missouri Basin drains an area of over 500,000 sq mi (4,049,700 ha) including all or portions of ten states and part of Canada, roughly one-fifth the geographical area of the continental United States.

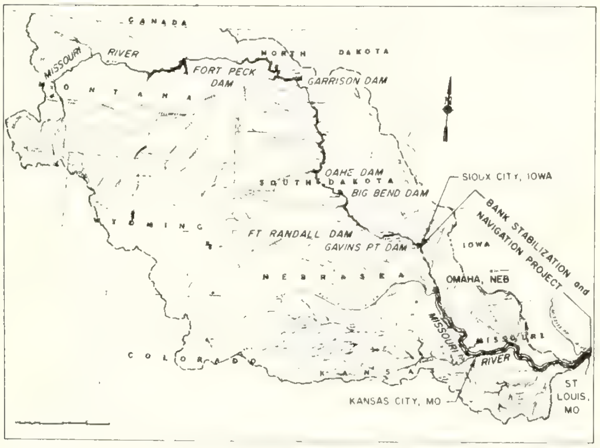

Figure 1.--Missouri River Basin Map

The Missouri River basin is one of vast contrasts with considerable climatical and geological variations. The average annual rainfall in the basin varies from less than 10 in (25.4 cm) in the semi-arid area to more than 40 in (101 cm) in the humid area located in the downstream portion of the basin. The river runs through canyons and rugged mountain terrain in the upper portion of the basin, through glaciated and unglaciated regions of smoothly sloping terrace lands and badlands, the hill plains of the central lowlands, and finally through the rugged upper Ozark Plateau before emptying into the Mississippi River approximately 15 mi (24 km) above St. Louis, Missouri. (Munger 1974)

Although flooding occurred on the Missour River at various times of the year, it has bee known for two major annual floods. The first generally occurred in April and lasted from on to two weeks. It was caused by the ice breaku and melting snow on the lowlands in the upper section, augmented by early rains in the lower section. The second annual flood, known as the "June Rise," lasted from three to five week and was caused by the melting snow in the mountains.

The Missouri River is unique because of i steep slope of approximately 1 ft per mile (0.000189) and rapid current with respect to its size. The average discharge downstream rom Sioux City, Iowa, varies from about 31,000 t^3/s (880 m^3/s) at Omaha, Nebraska, to about 4,000 ft^3/s (1,530 m^3/s) at Hermann, Missouri. he average velocities in this reach vary from bout 6 ft/s (1.8 m/s) at Omaha, Nebraska to bout 3.7 ft/s (1.1 m/s) at Hermann, Missouri. ecause of its rapid current and the alluvial alley through which it flows, it has throughout istory continued a process of scour and deposition. The natural river was in a constant state f change, relocating its channel by either radual bend migration or sudden cutoffs during flood. The river was characterized by shift-ng sandbars, constantly changing braided iannels, numerous snags, eroding banks, and ırshes. Today one can get some idea of what ie natural river looked like by viewing the) mi (80.5 km) of unchannelized river down-:ream of Yankton, South Dakota (fig. 2). The versity of environments available on this ver reach exemplifies habitats which have been st on the Missouri River. This may be an leal river environment for fish and wildlife. wever, the natural river was a constant threat private and public property located adjacent the channel and navigation was very diffi-lt, especially after the introduction of the eamboat.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Jul 16-20, 1979.

[2] Thomas D. Burke, Chief, River Developmen Section, Corps of Engineers, Kansas City, Missouri.

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;ure 2.--Natural River Near Vermillion, South Dakota

HISTORICAL DEVELOPMENTS AND RESULTS

Developments

Early records indicate that removal of gs from the Missouri River began as early 1832. However, with the exception of revet-t construction adjacent to some towns and construction of an occasional pile dike, very little construction was performed before the late 1920's. (Burke 1979) In 1912, Congress authorized a project to provide bank stabilization and develop a 6 ft (1.8 m) deep by 200 ft (61.0 m) wide navigation channel from Kansas City to the Mouth. Subsequent Congressional modifications, the latest being in 1945, extended the project limits to Sioux City, Iowa, and increased the design dimensions of the navigation channel to 9 ft (2.7 m) deep by 300 ft (91.4 m) wide. This was accomplished by (1) constructing dikes (structures perpendicular to the flow) to contract the channel width and close off secondary channels on the inside of the channel, and (2) constructing revetments (structures parallel to the flow) along the outside of the bend to provide uniform bank alinements and prevent erosion of the banks. Many cutoffs were also constructed on the river to eliminate sharp bends hazardous for navigation. Since 1890, construction of cutoffs and channel realinements shortened the river about 75 mi (121 km) to its present day length of 732 mi (1178 km) between Sioux City and the Mouth. (Corps of Engineers, Omaha District 1976)

During the period 1940 to 1964, six large multipurpose dams were constructed on the upper Missouri River. Gavins Point Dam, the farthest downstream, is located at Yankton, South Dakota, about 800 mi (1290 km) above the Mouth. These dams store water for flood control, irrigation, power production, and to supplement low flows for navigation.

The dikes constructed on the Missouri River for bank stabilization and navigation extend from the riverbank into the river, perpendicular or nearly perpendicular to the flow. They contract the river channel to the design width and protect the bankline from erosion. Some of the first dikes were several thousand feet long, extending from near the bluffs out to the desired channel location. These dikes cut off side channels and chutes, thereby concentrating the river flow into a single channel. Once the flow was contracted, additional shorter dikes were spaced intermittently around the inside of the bends. The revetment structures, constructed parallel to the flow, have been built either to establish and protect a desired bankline or to guide the flow along the designed alinement. These structures have been very effective in accomplishing their intended purpose -- stabilize the channel and banks, and develop a navigable channel.

Stabilizing the riverbanks allowed the landowner to clear and farm more of the fertile bottom lands adjacent to the river. However, the landowner was still faced with floods destroying his crops. Many miles of flood control levees have been constructed along the Missouri River. These levees, initially constructed by the individual landowners, were relatively low and overtopped by all major floods. In recent years, the lower levees have been replaced by larger ones to provide more dependable flood protection.

Results

The work done on the Missouri River has extensively changed the river from what it was when Lewis and Clark made their historic journey in 1804. The river no longer continuously moves the course of its channel throughout the valley as it once did, claiming entire farms and towns. Today the lower reach of the river flows in a single channel through gentle curving bends. By contracting the channel width and stabilizing the bank, a dependable navigation channel 9 ft (2.7 m) deep by 300 ft (91.4 m) wide has been provided. No longer do the two annual floods occur with dependable regularity. There is still occasional flooding caused by ice jams, heavy rainfall along tributaries, widespread rainfall throughout the basin, or combinations of the above.

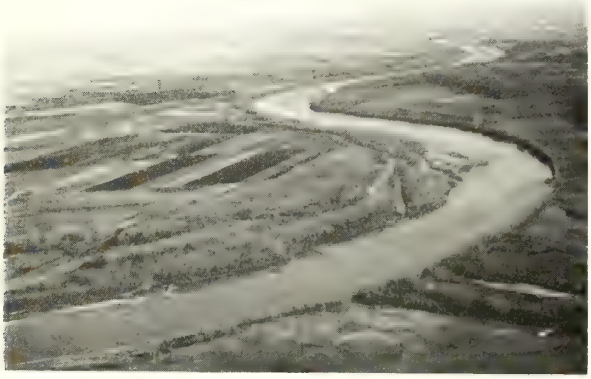

Figure 3.--Stabilized River Near Glasgow, Missouri

During the time the banks were being stabilized and the navigation channel developed, other changes occurred. By reducing the channel width from an average of about 3,000 ft (4800 km) to 1,100 ft (1770 km), nearly all the islands and side channels were eliminated. Due to the accretion of many acres of permanent lands, it is estimated that the water surface downstream of Sioux City, Iowa, has been reduced by about one-half. Funk and Robinson (1974) estimated the water surface area in the lower 500 mi (804 km) decreased from 121,700 acres (49,250 ha) in 1879 to 60,900 acres (24,645 ha) in 1972. The river today is a deep, fast flowing stream with very few quiet shallow water areas.

Eliminating the constant threat of erosion to valley improvements due to the migrating cha-nel has indirectly contributed to the further clearing of the flood plain for cultivation and subsequent loss of fish and wildlife habitat. Trees and other vegetation have been cleared fr thousands of acres of the flood plain. Along t lower 500 mi (804 km), the flood plain forest coverage declined from 76 percent in 1826, to 13 percent in 1972, and cultivated land increas from 18 percent to 83 percent. (Bragg and Tatschl 1977) The habitat diversity that once existed on and along the Missouri River has bee eliminated due to construction of the Bank Stab-lization and Navigation Project and clearing of the flood plain. The resultant impact upon fis and wildlife has been tremendous. The abundanc of many species has declined. The lake sturge is virtually extinct in the river, the number paddlefish has been greatly reduced, and large catfish (particularly the blue catfish) seldom are caught. The fishery of the Missouri River has declined significantly since the late 1940' a decline which closely parallels the physical changes in the river. Between 1947 and 1963 (16 years), the reported annual commercial harvest of fish declined about 80 percent, from 450,000 lbs (204,100 kg) to 90,000 lbs (40,800 kg). Recently the reported harvests have increased over the 1963 low, but have yet to rea those levels of the late 1940's. (Robinson 1979a) The whitetail deer is limited along th river by a lack of suitable forest cover and t once abundant river otter is rare. The elimin tion of quiet backwater habitat has adversely affected muskrats, mink, raccoons and use of t river by waterfowl.

The heights of flood flows have increased on the Missouri River due to the work in and along the river. This increase has been the result of a number of different actions includ ing levee construction, construction of dike and revetment structures, and highway and rail road fills. Preliminary studies by the Kansas City District, Corps of Engineers (1975a) indi cate that the major portion of this stage increase can be attributed to the construction o private levees. The levees, constructed close to the river banks, reduce the cross sectional area available for passage of flood flows. As a result, at above bankfull flows, the stage o elevation of the water surface has increased f the same discharge. These studies show that i the maximum discharge during the 1951 flood (modern day flood of record from Kansas City t Mouth) occurred today, the river stages would about 3 ft (0.9 m) higher.

STRUCTURE MODIFICATIONS

The Fish and Wildlife Coordination Act of 1958 provides an opportunity to restore some of the lost habitat diversity. A number of structure design changes have been made to reduce permanent land accretions which encroach upon the flood carrying capacity and eliminate fish and wildlife habitat diversity along the river. The modifications were the result of numerous meetings and joint field inspections by representatives of the Missouri River Division, Corps of Engineers, and Federal and State Fish and Wildlife Agencies. The major structure modifications developed and used to date are: (1) notched structures, (2) low elevation structures, (3) rootless structures, and (4) chute closure structure modifications. (Corps of Engineers, Kansas City District 1975b). When selecting the type of modification to use, one must consider such items as the capability of the structure to provide suitable diverse habitat, the effect of the structure upon navigation and bank stabilization, adjacent land use, and landowner acceptance.

Notched Structures

The notches in structures are 20 to 100 ft (6.1 to 30.5 m) wide and are 3 to 12 ft (0.9 to 3.7 m) lower than the remainder of the structure. The location, number, and size of the notches are determined by existing field conditions. Since 1974, approximately 1100 structures have been notched. This includes 150 new structures built with a notch, 400 structures repaired leaving a section unrepaired, and 550 existing structures in which rock was excavated from the structure.

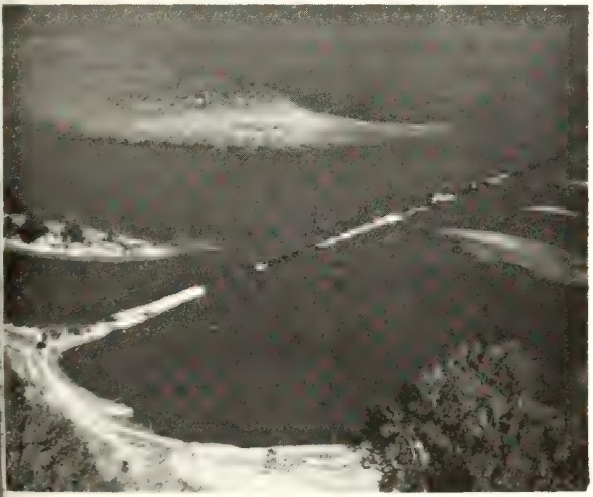

Figure 4.--Notched Dike Near the Mouth of Osage River

The purpose of the notch is to allow water to flow through the structure to develop or preserve side channels and prevent further land accretion. The majority of the notched structures have caused the formation of small chutes of water with submerged sand bars, as they were intended to do. Notched structures increase or maintain twice the aquatic edge and provide a diversity of habitats.

Low Elevation Structures

In 1975, the design elevation of dikes was lowered 4 ft (1.2 m) to an elevation which is below the water surface 95 percent of the time. The structures are built to this lower elevation because of reduced cost, potential for habitat improvement, and decreased effect upon the flood carrying capacity of the channel. If a structure does not adequately develop the navigation channel, it can later be raised. The low elevation structures have prevented high accretion elevations that can support permanent vegetation and have been effective in developing more diverse water depths. A deep hole usually develops immediately downstream from the structure, and a submerged bar 2 to 5 ft (0.6 to 1.5 m) below water surface develops downstream from the structure.

Rootless Structures (Vane Dikes)

The rootless structures are a modification of the notched structure. They are dikes constructed perpendicular to the flow without being tied into the bank. They are 150 to 300 ft (45.7 to 91.4 m) long, with the landward end of the dike located 50 to 250 ft (15.2 to 76.2 m) from the bank. The vane dike is similar to the rootless dike except its alinement is 15 to 30 degrees downstream. The purpose of the rootless structure is similar to the notched structure, i.e., to allow water to flow between the structure and the bank to prevent accretion. Because these structures are not attached to the bank, flow around both the landward and riverward end of the structure provides potential for development of multiple sub-channels and creating more aquatic edge. Field inspections and surveys of these structures indicate excellent results. There has been little, if any, silting in between the structure and the bank, a flow has developed on the landward side of the structure, and a low sand bar develops downstream. A potential erosion problem exists with this type of structure because of the flow between the dike and the bank. Therefore, the distance between the bank and the landward end of the structure and the adjacent land use must be considered. Vane dikes have been constructed at four locations. Accretion has occurred between the vane dikes and the bank at these locations, primarily because of the length and spacing of the dikes. Using shorter structures and/or longer spacing will reduce the amount of accretion and produce additional habitat diversity. Because of the lower cost and excellent results achieved with the rootless dike, a lower priority has been placed on the construction of the vane dikes.

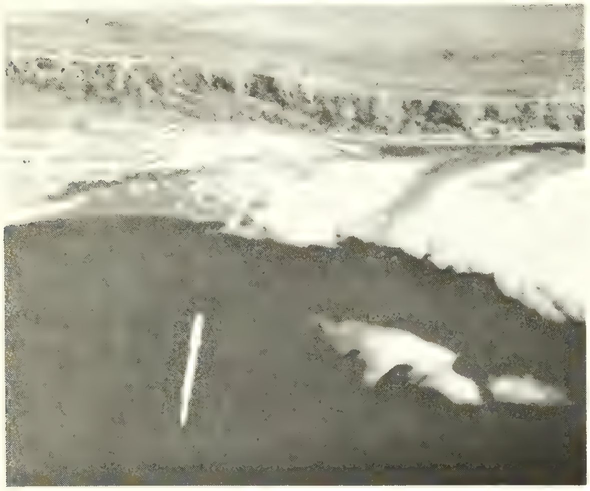

Figure 5.--Rootless Dike Near Arrow Rock, Missouri

Chute Closure Structures

Many of the chutes along the Missouri have been closed off by constructing pile or rock structures across them. The structures, as originally constructed, allow flow through the chute only during times of high water. To allow flow through the chute at normal or low stages, a portion of the structure is lowered similar to the notched dike or pipes are installed in the structure. The structures which have been notched are generally working satisfactorily. However, on three structures where 30- to 48-in (76 to 122 cm) diameter pipes were installed, the pipes became plugged with debris and silted shut.

Although construction of the notches or low sections in the chute closure structures have performed satisfactorily, it is not always possible to do this type of modification. At most locations, private landowners have obtained title to the islands and started cultivating portions of them. They use the chute closure structures for access to their land, and cutting a hole in the structure would prohibit this access. Therefore, emphasis is being placed on developing some type of inexpensive, large culvert or bridge that will allow free flow of water through the chute, but still allow access to the island.

CONCLUSIONS

Dike and revetment structures which have been used to stabilize the banks and develop a navigation channel in the Missouri River have eliminated considerable fish and wildlife habitat, and substantially reduced habitat diversity. Structures constructed to high elevations cause permanent land accretions. The transformation of the river into a single channel has resulted in the elimination of most side channels, islands, backwater areas, and sloughs which are important feeding, nursing, resting, and spawning areas for fish and wildlife. Little or no work was done to improve or maintain fish and wildlife habitat diversity during construction of the Bank Stabilization and Navigation Project.

Structure modifications begun in 1974 are an attempt to improve conditions for fish and wildlife. The notching of structures shows promise because the notch helps to create small side channels which increase habitat by at least doubling the aquatic edge. Without notches or some other type of modification, experience shows that land accretion occurs and existing wet areas become permanent land often cleared and cultivated, unusable by aquatic life. The objective in modifying structures is to stop permanent land accretion and encourage the river to develop aquatic habitat usable at various water levels by fish and wildlife. Lowering the height of structures appears to have effectively eliminated, or at least slowed down, land accretion. Sand bars form at levels low enough that permanent stands of willows and cottonwoods do not become established. These lower level structures appear to be successful in maintaining the navigation channel; and, if notched or not attached to the bank (rootless), are providing aquatic habitat that can be utilized by fish and wildlife at various water stages. Rootless structures offer many possibilities in the development of diversity and aquatic edge because of flow patterns over these structures, as well as around both ends. The riverward flow aids navigation, while the land flow erodes a small channel next to the bank. Both notched and rootless structures are being used to provide flows into and around sand bars and islands.

It is nearly impossible to demonstrate that the modified structures have improved the fish populations of the Missouri River because of the difficulty in sampling in a big turbid river. Structure preference by fish species is also difficult to demonstrate in a big river environment where radical habitat changes occur annually due to water level fluctuation and varying amounts of ice cover. The duration, frequency, and height of water levels and their relationship with the amount of ice cover may have more effect on which structures various fish species use than the type of structure modification. Therefore, the total benefits provided by these structures may not be known for several years.

Personal observations and results of studies indicate that the modified structures are desirable (Robinson 1979b). Flathead catfish, freshwater drum, and blue sucker appear to prefer the fast water provided by notches. Consequently, the notched structures are preferred fishing areas by many pole and line fisherman. Shallow sand bars provide nursery areas for young fish and minnows, and harvest areas for blue catfish, channel catfish, freshwater drum, and shovelnose sturgeon. The deep holes created adjacent to the modified structures provide concentration areas for fish during winter low flow periods.

It appears that the land accretion process can be stopped by using modified structures. It is also obvious that a diversity of habitat available at varying water levels is important. When water levels exceed the top of the structures, such as during a flood, the amount of habitat (and diversity) available to the fish population is lowest because most quiet water areas are lost and the aquatic edge is considerably reduced. The river then becomes free flowing and swift bank to bank. Diverse aquatic habitat can be developed by utilizing a variety of environmental structure designs (high, low, notched, angled, rootless, and combinations thereof) that will improve conditions for big river fish and wildlife populations at all water levels. The goal of stopping or slowing land accretions and creating habitat diversity are now being realized in many reaches of the Missouri River. Once the limiting factors for certain species of fish and wildlife are better understood, it may become possible to modify structures and develop areas to improve conditions for specific species.

Great care and expertise will be needed by both the biologist and engineer to create a diverse aquatic habitat at various water levels without causing further land accretion, permanent water surface losses, bank erosion, or impairing the usefulness of the navigation channel.

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Ecological Mitigation: A Viable Option in the Federal-Aid Highway Program[1]

Charles R. DesJardins[2]

Abstract.--This paper provides an overview of ecological mitigation activities that are an integral part of Federal-aid highway project development. Case studies are cited as well as project coordination, agency staffing, training, publications and research.

INTRODUCTION

I am pleased to represent the Federal Highway Administration (FHWA) at this important and timely symposium. We can learn a lot from each other to stimulate our powers of inquiry and ultimately better shape human activities to their surroundings.

ENVIRONMENTAL IMPACT STATEMENT PROCESS

Under the Federal-aid highway program, the Federal Government and the States operate in partnership. The State highway agencies initiate, plan, design, build, and operate the highways within their jurisdictions while the FHWA provides guidance and financial assistance at key points in the process. For the States to obtain financial assistance, they must comply with all applicable Federal laws and regulations, which include environmental statutes that apply to highway programs. The most important environmental statute to date is the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 432-4347). The NEPA requires that an environmental impact statement (EIS) be prepared for "major" Federal actions significantly affecting the quality of the human environment. An EIS points out adverse effects which can be reduced or eliminated, as well as those impacts which are unavoidable.

During the environmental assessment process, other environmental requirements are triggered. One important requirement, and the focus of this symposium, is compliance with the Fish and Wildlife Coordination Act (16 U.S.C. 661-666).

Since transportation projects frequently cross streams or bodies of water, Fish and Wildlife Coordination Act consultation is often necessary. A sampling of EIS's revealed that 65 percent of the proposed highway projects required consultation. Therefore, it is important to FHWA that measures to mitigate adverse impacts be understood within our own agency as well as to share these experiences with others. The question surfaces: - is mitigation a viable option?

CASE STUDIES

Here are a few success stories from variou State highway agencies. Many mitigation techniques have been attempted; some are successful and some are not. Many reasons may be listed for these successes and failures. The highlights of selected case studies are as follows.

Tennessee, State Route 29.--Two ponds were created from borrow pits which furnished materi for the roadway. These ponds were dug deep enough so that the ground water aquifer will continually furnish water year round. During periods of high water, these ponds will trap flood flows and gradually release the excess water back into a stream. Mounds of earth have been created to act as habitat for many of the small mammals, especially during high water flow. (FHWA News, April 1979).

North Dakota, I-94.--Long-term studies hav indicated that the quality of various waterfowl can be enhanced by highway mowing practices.

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[1] Paper presented at The Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979

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A comparison of the number of waterfowl nests in mowed and unmowed areas of the right-of-way indicated at least a 50 percent increase in the unmowed areas. The following recommendations were made as a result of observing the area to maximize waterfowl production.

1. Delay mowing until well after the peak of waterfowl nesting.
2. Leave interchange areas unmowed.
3. Leave ditch bottoms and back slopes unmowed.
4. Set up a rotational mowing policy at 3-year intervals with only one side of the right-of-way being mowed during any 1 year.

This study also revealed that there was a higher density of nest success in the right-of-way areas compared to non right-of-way areas. The increased nest success has not been clearly understood; however, the investigators in the I-94 study believe that high speed traffic and other barriers acted as a deterrent to the activity of red foxes, which are significant predators.

New Mexico, I-40.--Research conducted on I-40 as well as in many other States indicates that special treatment including post construction refertilization of plant material is necessary to reduce soil erosion and to create improved habitat for wildlife. The placement of plantings on new cut and fill areas where sterile soil is prevalent subjects each plant species to a harsh environment. Although research conducted for as long as 30 or 40 years indicates the importance of continued plant care, this project emphasizes that appropriate treatment for stabilization plantings must be determined on a project-by-project basis. Also frequently overlooked by highway agencies is that disturbed soil needs periodic refertilization based on soil analysis.

Colorado, I-10.--An important area of concern, especially in the western United States, s the incorporation of features in project esigns to allow for the seasonal migration of eer across a highway corridor. In addition to easonal activities, individual deer trapped ithin highway rights-of-way must be able to et out. Eight different types of one-way eer gates were developed and tested to allow nimals to escape from the highway. On the asis of these studies, it has been recommended hat the installation of one-way gates be considered wherever 8-foot fencing adjacent to the ighway is used to reduce or prevent eer-vehicle accidents and to maintain the cological needs of the species.

West Virginia, 48.--Highways can result in greater species diversity. Field studies were undertaken in West Virginia in order to measure the impact that this highway had on wildlife. The diversity of small birds and mammals and the numbers of individual species increased substantially on the rights-of-way, highway edges, and in nearby forests. It is anticipated that this diversity will in turn increase the numbers of larger animals.

Oregon, numerous highway projects.--One important concern in crossing streams is not to disrupt the movement of fish both upstream and downstream. The length and shape of roadway drainage is a factor important to fish passage. Each location must be carefully studied. In Oregon, different types of culverts have been evaluated. These included reinforced concrete box culverts, structural plate pipe culverts, structural plate arch culverts, open bottom culverts, corrugated metal pipes, and multibarrel culverts. Mr. Thomas J. McCellan, in his publication--"Fish Passage Through Culverts," 1970, Office of Engineering, FHWA, presents a thorough evaluation of these facilities.

Georgia, I-95.--The alternatives for this Interstate along the coast of Georgia were carefully studied prior to selecting an alignment. A team of highway professionals and ecologists identified two important areas of concern:

1. the location and impact of dredge-spoil areas in marshes, and
2. the revegetation of these spoil areas.

Aerial and ground studies conducted by ecologists from the Institute of Ecology at the University of Georgia resulted in numerous recommendations for preserving important wetland areas, including the following:

1. locate dredge-spoil areas in those marshes having lesser biological productivity, and
2. deleting stream relocations.

GENERAL DISCUSSION

It appears from this brief review of a few selected projects that many mitigation and enhancement opportunities exist. Many more, and perhaps better, examples are known to those of you in this room. The potential for creating wetlands, improving stream habitat, diversifying wildlife habitat, and many other similar features is tremendous. Other factors also play a role in mitigation efforts.

The timing of construction activities is often very important. For example, a 1 year anadromous fish run of salmon could be severely impacted by the improper timing of construction. An endangered species mating season could be adversly affected by construction noise. The potential for controversy lurks at every bend in the road, but with very little extra effort we can improve our natural surroundings at the same time we improve our transportation systems.

Highway rights-of-way are receiving increased attention for their potential in producing crops such as hay or pulp wood. In some agricultural and even urban areas of the United States, these rights-of-way often provide the only undisturbed vegetation which in turn provide nesting grounds for birds, burrowing areas for small mammals, and other types of shelter for many animals. A "green" buffer strip is also valuable as a visual amenity for both the highway user and highway neighbor.

COORDINATION

The FHWA endorses early and continuing coordination between public works agencies and those agencies mandated to conserve and manage wildlife resources. This effort is one of the most important to complete and also one of the most difficult to accomplish. Specific details for a highway design may not be available or do not provide the depth of detailed information desired by a wildlife agency at the early planning phases. It should, however, be sufficient to discuss major design issues that would be considered for various alternatives. The fish and wildlife agencies are likewise responsible to advise the highway agency of the resources likely to be impacted in the project area.

STAFFING

During the last 10 years, additional disciplines have been added to the professional staff of the FHWA, especially at the Washington Headquarters and the Regional Office levels, to assist in the environmental analysis of highway projects. These additional disciplines include ecologists with both aquatic and terrestrial expertise, biologists, landscape architects, geographers, archeologists, historians, and engineers specializing in acoustics and noise. The FHWA also administers a 30-month environmental training program for entry level professional employees (non-engineers). Academic as well as on the job experience is gained in the Washington Headquarters, the Region, the Division, and at State highway agencies. Upon completion of this training, the employee is given a permanent assignment in a Regional Office or at Headquarters.

Each State highway agency has an environmental action plan which identifies the staff that is needed to provide an interdisciplinary capability. Since the State highway agency develops the actual highway project, the presence of environmental specialists in these organizations is critical. Our experience indicates that where highway agency bioligists can work early and directly with fish and game biologists at the field level in the project development process, major problems very seldom occur at a later time.

TRAINING

The FHWA utilizes several avenues to spread the word on the importance of fish and wildlife mitigation measures in the planning, location, design, construction, and maintenance of highway facilities. The FHWA has developed several training courses which vary from several days to 1 week in length. These courses and workshops provide an opportunity for engineers and biologists to learn new information and to share their operating experiences, both successes and failures. The following are examples of training courses developed and presented by FHWA

Course Title	No. of Courses	Total Students
Ecological Impacts of Proposed Highway Improvements	41	1,160
The Impact of Highway Systems on Water Quality	32	950
Preparation of Environmental Impact/4(f) Statements	48	1,559

Additional training opportunities continue to be developed. A workshop on water related policy issues for FHWA and State highway agency personnel is currently being conducted in every FHWA region. The subject matter includes permit processing (primarily Section 404), flood plain management, coastal zone management, wetlands, ground water aquifers, and the Fish and Wildlife Coordination Act proposed rulemaking. Seminars are also held. Recently Dr. Mel Schamburger of the U.S. Fish and Wildlife Service gave a presentation on Habitat Evaluation Procedures (HEP) to the FHWA Washington Headquarters staff.

PUBLICATIONS

In March of 1978 the FHWA published a report titled Highways and Ecology: Impact assessment and Mitigation. The report pulls together in a single 182-page volume an abbreviated overview of the Ecological Impact of Proposed Highway Improvement training course material in addition to descriptive information relating to mitigation case studies. A recent letter from Secretary of the Interior Andrus to Secretary of Transportation Adams states, "I feel certain that if everyone will give attention to the terrestrial, aquatic, and wetland sections of the report in their consultation activities, field level resolution of concerns should occur." An 8-page pamphlet titled "The Importance of Ecology in the Federal-Aid Highway Program" is also available to answer the more general questions which are often raised.

RESEARCH

Information concerning fish and wildlife-related matters is also being disseminated as a result of research conducted by FHWA and the State highway agencies. Some examples of important research efforts underway are:

1. Effects of Highway Runoff on Receiving Waters: This research project is studying ways to reduce environmental hazards to water resources due to highway systems. The study has four objectives: (1) to characterize the pollutional aspects of highway runoff, (2) to identify the sources and transport mechanisms, (3) to define the magnitude and the extent of the impact on receiving waters, and (4) to develop mitigation strategies to abate these impacts.

2. The Evaluation of Tidal Flat Areas for Highway Planning and Design
The objectives of this research are to: (1) develop a method to evaluate tidal flat areas found within coastal wetlands and (2) develop a procedure to incorporate tidal flat values into highway planning decisions for routing through coastal wetlands.

3. Effects of Highway Operations Practices and Facilities on Elk, Mule Deer, and Pronghorn Antelope.
The research will evaluate the impact of snowfence, shelterbelts and sagebrush stripping upon elk, mule deer and pronghorn antelope.

4. Ecological Evaluation of Wildlife Populations and Habitats Affected by Highway Development in Major Geographic Areas of the United States.
The purpose of this research is to determine the effects of highway operation and construction on the diversity and special distribution of wildlife species and their habitat. A product of this research will be the development of a system to predict and evaluate the impacts of highways on plant and animal communities.

Much research remains to be undertaken. We anticipate that this symposium will assist us by making us more aware of the efforts of others and of their anticipated results.

CONCLUSION

The FHWA endorses the concept of responsible mitigation. We believe that a Federal-aid highway should be a good neighbor. Fish and wildlife mitigation can be accomplished. I have documented that it can and has worked when handled with care and concern. However, much remains to be accomplished. Communication and trust will continue to be key elements in the future; and most importantly, our successes and failures in fish and wildlife mitigation and enhancement need to be better documented so that future generations can benefit from our experiences. Yes, mitigation is a viable option.

Highways and Wildlife - Some Challenges and Opportunities for Management[1]

Jerome A. Jackson[2]

Abstract.--Potential management of highway rights-of-ways as habitat corridors linking isolated islands of wildlife habitat are discussed. Particular emphasis is placed on the potential to manage highway rights-of-ways to benefit some endangered species.

The interstate highway program was born in 1956 and the past 23 years have seen over 41,000 miles of these major arteries completed to form an intricate transportation network that blankets the contiguous 48 states (Mayer 1958, Jordan 1968). Associated with the development of this system has been the acquisition of more than 1.6 million acres of land for highway rights-of-ways (Jordan op. cit.). Typically these rights-of-way lands were cleared during construction activities, then seeded with grasses or planted with other types of low vegetative cover. Basically, however, these lands have been removed from economic productivity and have been modified and managed such that they provide a less than optimum environment for most native plants and animals. Rights-of-ways often seem to be regarded as simply the necessary buffer between the lanes of traffic and other human activities, and considerations for management of rights-of-ways seem to be primarily safety and aesthetics.

Simultaneous with the development of the interstate system have been growth in human populations and human developments that have further depleted land resources available for food and fiber crops and for wildlife. Increased demands on land resources have given rise to inflation and to many of the environmental problems that have been recognized in recent years. Some unique North American ecosystems have been so disturbed or fragmented by human developments that some species' numbers have dwindled to the point where they are recognized as being endangered. While interstate highway construction has directly and indirectly resulted in decreases of some species, others have benefited from the development.

In this paper I will document some positive wildlife relationships with interstates and explore some possibilities for highway development and right-of-way management that might further benefit wildlife. One point of emphasis I will consider is the potential for developing interstate rights-of-ways as habitat corridors between still existing fragments of endangered ecosystems.

Interstate Corridors and the Swallows' Flight to the Sea

Sherman's march to the sea took less time, but the range expansion of barn swallows (Hirundo rustica) through the south to the sea has been no less successful. Pindar (1926) considered the barn swallow a rare breeder in northwest Georgia, and Howell (1924:264) cites a nesting record from northwest Alabama in 1892. The first nest discovered in north Mississippi was found in the northeast corner of the state in 1938 (Warriner 1938). There were no breeding records for barn swallows in north Louisiana until 1964 (Stewart 1964). Contrary to Bent (1942), a small breeding population of barn swallows was known on the Atlantic coast of Georgia prior to 1904 (Burleigh 1958) and isolated breeding populations were known from the Gulf coast of Louisiana, Mississippi, and Alabama by 1940 (McIlhenny 1933, 1935; Burleigh 1941, 1942, 1944). Weston (1947) discovered the first nesting barn swallows on the Gulf coast of Florida in 1946. These populations have expanded along the coast (Chandler 1964, Weston 1965, Stewart 1970, Reid 1975) but apparently have not dispersed far inland.

The tremendous population explosion and range expansion of barn swallows to bridge the more than 300 mile gap between coastal and northern populations took place in the 23 years since initiation of the interstate highway system. It has involved a population increase followed by a progressive southward dispersal of northern populations. Since 1964 the range expansion of barn swallows into the southeastern U.S. has been rapid and steady. In 1970 the species was first noted nesting inland in north Florida (Ogden 1970). Peake and Baker (1967), Kennedy (1974), and Reid (1975) have summarized some regional information on barn swallow breeding range expansion in the southeast. At the present time the species has essentially closed the gap between northern and coastal breeding populations in Louisiana and Mississippi. The gap in western Alabama, Georgia, and Florida is nearly closed (personal observation, Denton 1976). Details of the range expansion have been relatively well documented, though scattered, in the pages of American Birds, The Mississippi Kite, Alabama Birdlife, The Oriole, and The Chat.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Professor of Biological Sciences, Mississippi State University, Mississippi State, Mississippi.

Without exception the initial reports that I have found of barn swallows nesting in a new area have noted that the nests were under a bridge or in a culvert associated with a road and frequently with an interstate. Jackson and Burchfield (1975) demonstrated a preference of barn swallows for concrete as opposed to wooden bridges as nest sites and discussed potential advantages to the birds using concrete bridges. They (op. cit.) also documented a transition from wooden to concrete bridge construction since the 1940's and noted that in Mississippi the state highway department had constructed 1522 concrete bridges since 1956.

The interstate highway system with its broad, open rights-of-ways and multiple bridges became not only major human transportation routes, but also corridors that facilitated dispersal of pioneering barn swallows. Can interstate rights-of-ways be managed to create habitat corridors that might allow dispersal of an endangered species among isolated populations and thus increase their chance for survival?

Highways for Endangered Species

There is a long history of wildlife losses to highway traffic and for many species management of highway rights-of-ways as wildlife habitat might not be advisable. On the other hand, there are some species whose needs and behavioral patterns are such that they could live in proximity to a major highway. In this section I will discuss the potential for mitigating the effects of highway construction on some of these species by managing rights-of-ways as habitat corridors to benefit them.

The red-cockaded woodpecker.--The red-cockaded woodpecker (*Picoides borealis*) is endemic to the mature open pine forests of the southeastern United States. It is federally listed as an endangered species primarily as a result of habitat losses and associated population declines. While this species still enjoys a wide distribution, its populations are becoming increasingly fragmented. Figure 1 illustrates the location of some major red-cockaded woodpecker populations and the interstate highway network that offers the potential of providing corridors among them.

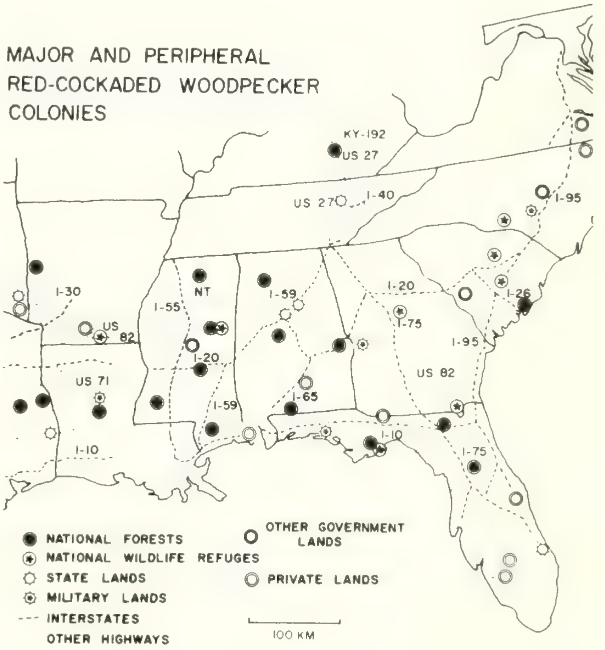

Figure 1.--Some major red-cockaded woodpecker population centers and potential corridors among them.

The red-cockaded woodpecker typically requires 70-year-old or older living pines for excavation of its nest and roost cavities (Jackson et al. 1979). It also prefers relatively open stands that naturally would be kept open by fire, but that can be kept open by mowing. Several red-cockaded woodpecker colonies are known along interstate rights-of-ways, including sites in Mississippi, Alabama, Georgia, and South Carolina (Jackson 1976 and personal observation). Red-cockaded woodpeckers learn to tolerate normal traffic noises and I have found them successful in rearing young within ten meters of traffic along interstate 59 north of Birmingham, Alabama. This does not mean that the birds cannot be disturbed - even to the point of nest abandonment (R.W. McFarlane, pers. comm. and personal observation) - by excessive noise. The birds seem to acclimate to noise over a period of time and can be initially disturbed by it. Thus, noisy human activities should not be initiated near a red-cockaded woodpecker colony during the nesting season.

From the birds' point of view, management of interstate rights-of-ways for red-cockaded woodpeckers requires four major considerations: (1) concentrating management efforts where there are stands of pine forest adjacent to the right-of-way, (2) allowing pines to grow to an age of 70 years or older, (3) maintaining a relatively open understory associated with the pines, and (4) maintaining a tree density along the right-of-way of between 40 and 80 square feet of basal area per acre. The first of these considerations is simply to maximize benefits for the species. Unlike other woodpecker species of similar size, red-cockaded woodpeckers have exceptionally large home ranges - averaging 200 acres or more depending on habitat quality (Skorupa and McFarlane 1976; Nesbitt et al. 1978; Jackson personal observation). Because of its linear nature, a managed right-of-way alone would not likely support a clan of red-cockaded woodpeckers. The right-of-way could, however, provide an adequate area for all of the clan's cavity trees. Adjacent pine forest could be commercial stands managed on shorter rotations and still be of use as foraging habitat for red-cockaded woodpeckers. As Jackson (1976) suggests, forest industry could maximize their efforts to assist this species by managing their lands near interstates to supplement the habitat corridors being developed on rights-of-ways.

The second consideration - allowing pines to grow to ages of 70 years or older - doesn't seem to be much of a problem since trees along interstates are typically just left to grow unless a question of safety arises. Older trees would have to be kept back a safe distance from pavement, but rights-of-ways are often very wide, particularly at interchanges. Also, with lower maximum speed limits, trees may not have to be kept as far from traffic.

Maintaining a relatively open understory poses more problems, but is important for more than the birds. An open understory provides less cover for deer and other large mammals and would thus be important in reducing the potential of wildlife-vehicle accidents. Prescribed burning would be the preferable means of controlling the understory from an ecosystem point of view since periodic lightning caused fires were probably the dominant factor in the evolution of southern pine forest ecosystems. Other endangered and threatened species of southern pine forest ecosystems would also directly benefit from use of prescribed burning as opposed to other methods of understory control. These include such animals as the gopher tortoise (Gopherus polyphemus), eastern indigo snake (Drymarchon corais), and a number of species that use gopher tortoise burrows (Mount 1976). Some endangered and threatened plants, such as the linear pipewort (Eriocaulon lineare), might also benefit from this type of management (Hardin 1977). Fire, of course, has drawbacks in terms of potential smoke hazards for motorists, but prescribed burning can be accomplished such that smoke production is predictable and managed and it should not be overlooked as a potential right-of-way management tool. Use of prescribed burning would eliminate the buildup of combustible litter along roadways and lessen the probabilities of wildfire. In the southeastern U.S. prescribed burning is a well-studied science (e.g., Brownand Davis 1973; Pharo and Hauck 1975, Pharo 1976, Mobley et al. 1976) and it would certainly be possible to carry out some burning of rights-of-ways with minimal potential for hazards to motorists. In most southern pine forests, prescribed burning at about three-year intervals is optimal for managing red-cockaded woodpecker habitat. Perhaps the largest problem with the use of prescribed burning of interstate rights-of-ways would be a public relations one - Smokey the Bear has done his job too well and many Americans are unaware of the positive ecological values of fire. Mowing and the selective use of herbicides are alternative understory control methods that might be used, though each of these also has drawbacks. Mowing would eliminate natural regeneration of the pines. Herbicide control, like fire, leaves dead or dying vegetation that is aesthetically unpleasing. Use of some herbicides is also being questioned because of their potential effects on non-target organisms. Economics also seems to favor prescribed burning for right-of-way maintenance. Arner et al. (1976) found that prescribed burning of a gas line right-of-way could control brush at less than half the cost of mowing and 1/6th the cost of using herbicides. They place the cost of burning at $3.60 - 15.40 per acre. Mobley (1976) estimates the cost of prescribed burning of southern pine forests at $.20 - $2.50 per acre.

The Mississippi sandhill crane.--The Mississippi sandhill crane (Grus canadensis pulla) is a species that has caused highway developers some major problems and that has major problems of its own as a result of highway developers. This resident population of perhaps fewer than 40 birds is now confined to Jackson County on the Mississippi coast (Valentine and Noble 1970). The region has undergone considerable development in recent years and little suitable habitat for the birds remains (Fig. 2). Interstate 10 along the Gulf coast is essentially completed in Mississippi except for a short section which would cross the cranes' nesting grounds. Court injunctions temporarily blocked interstate construction,

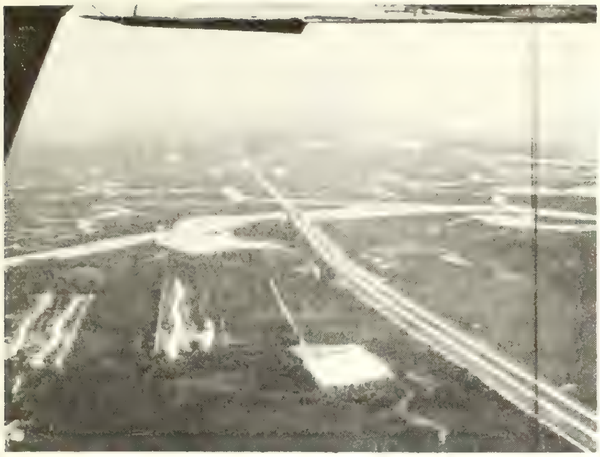

Figure 2.--This is a view looking east towards the Pascagoula River from above the Mississippi Sandhill Crane National Wildlife Refuge. Savannas at the bottom of the picture on both sides of Interstate 10 are used by the cranes. Note the encroachment of suburbia on their habitat. Such developments surround the crane's last nesting areas.

but a compromise was eventually reached whereby the interstate would go through with one interchange deleted. Meanwhile, a National Wildlife Refuge for the cranes has been established in the area. Survival of these birds will be dependent on carefully controlled development in the area. The interstate without the interchange near the crane habitat may be a positive barrier to developers that will benefit the cranes. While Mississippi sandhill cranes are susceptible to human disturbance at their nest sites (Anon. 1975), they seem to be somewhat tolerant of vehicular traffic near where they are feeding. For example, two Mississippi sandhill cranes were seen by an airport employee feeding in a mowed area about 50 yards from the active runway of the Gulf Park airport near Ocean Springs on the morning of 14 April 1979. If drainage patterns along the interstate are managed to allow some accumulation of water - as was typical of the original pine flatwoods environment of the area - and if the rights-of-ways are managed to perpetuate the pine flatwoods botanical community, the effective size of crane refuge might be substantially increased. The cranes may infrequently use the actual right-of-way, but the visual continuity of the adjacent refuge habitat with the right-of-way might provide at least a "psychological" increase in habitat available to the birds.

As with the red-cockaded woodpecker, prescribed burning of this crane's habitat may be important to its survival (Valentine and Noble 1970). Known nesting areas of the cranes are scattered within Jackson County (Valentine and Noble 1970; pers. observ.) and the Mississippi Sandhill Crane National Wildlife Refuge is divided into two units that are separated by approximately two miles of non-refuge land (Valentine et al. 1976). Properly managed road rights-of-ways in the area could serve as habitat corridors among nesting areas and feeding areas. Utility line rights-of-ways could easily provide similar corridors for the birds, but such development might not be advisable unless the lines are placed underground. Collision with utility lines is a known cause of mortality among sandhill cranes (Walkinshaw 1956).

Attwater's Prairie Chicken.--The vast grasslands of south Texas and southwestern Louisiana once supported a large population of Attwater's prairie chicken (Tympanuchus cupido attwateri) (Lehmann and Mauermann 1963). In the past few decades, however, these prairie lands have been subjected to intensive agricultural use and the chicken populations have declined precipitously (Lehmann 1968, Brownlee 1972). Rice and soybean fields and heavily grazed pasture are the inhospitable seas that make islands of the scattered remnants of the original tall-grass prairie ecosystem. Efforts to save this unique bird have included establishment of the Attwater Prairie Chicken National Wildlife Refuge, management for the species on part of Aransas National Wildlife Refuge, and encouraging landowners to protectively manage other isolated populations. Periodic burning of the prairie seems to be important for the long term survival of the species, but results in a need for the species to shift its populations to take advantage of the optimum stages of prairie development following a fire (Lehmann 1965, Chamrad and Dodd 1972). To some extent this need is being satisfied by transplanting prairie chickens from one area to another (Lehmann 1968), but this is not always possible and the birds still disperse naturally, attempting to cross inhospitable habitats in search of new breeding and feeding areas. Interstate rights-of-ways, because they tend to be quite wide, could be managed to provide habitat corridors for prairie chickens. Lehmann (1941), Robel et al. (1970), and Bowman and Robel (1977) document that dispersal in this species occurs during the fall and winter months. Thus it would be important that any mowing along the corridors be done early enough in the season to allow late summer development of prairie grasses and weeds that will provide winter cover and late enough (after July 1, Lehmann 1941) to protect nesting birds and small young. Lehmann (1941) also suggested that burning activities be completed before February 1 so as not to disrupt courtship activities. Some prairie chickens are killed by automobiles on the highway (Lehmann 1941), but the presence of suitable nesting and feeding areas in rights-of-ways likely outweighs the added mortality factor. As with other species, a good public information program within the range of the prairie chicken might facilitate implementation of positive management for the species on some private as well as public lands.

Other Opportunities

With the few examples thus far I hope to have supplied sufficient detail to impress the reader with the potential for deriving added wildlife benefits through selective management of highway rights-of-ways. There are many other species that could have been used as examples. Whitaker (1974) found that eastern phoebes (Sayornis phoebe) and barn swallows would readily use artificial nest sites attached to culverts. Many species of bats are known to occasionally use bridges as roost sites (Davis and Cockrum 1963). Perhaps slight modifications in bridge design might prove attractive to some of our endangered bat species; perhaps the undersides of some bridges could be modified to form artificial "bat caves" to which bats could be transplanted from a maternal colony of an endangered species. Huey (1941) discussed how a western highway served as a corridor for the dispersal of pocket gophers (Thomomys); perhaps with proper management highway rights-of-ways could similarly benefit endangered or threatened rodents such as the Moro Bay kangaroo rat (Dipodomys heermanni morroensis).

Clearly there are new challenges ahead in wildlife management - perhaps the largest being the maintenance of some ecosystem integrity in the face of human exploitation of our natural resources. Corridors similar to those I have suggested may be missing links that can insure maintenance of natural diversity for future generations.

I would like to conclude by quoting from an editorial in the Los Angeles Times of 2 December 1976 titled "Corridors of Sanity:"

> "It's a nice idea, these corridors of trees rambling across America alongside the freeways and byways, linking the islands of isolated woodpeckers and bobwhites one to another, and to us."

Acknowledgments

I gratefully acknowledge the financial support of the U.S. Department of Energy for my research on red-cockaded woodpeckers at the Savannah River Plant, South Carolina. This paper was developed incidental to those studies. Bette J. Schardien provided helpful criticism of an earlier draft. Lyda Eubank skillfully typed both early and final drafts.

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Arkansas - The Mitigation Experience[1]

Richard W. Broach[2]

Federal water resource management projects have produced profound ecological changes in Arkansas with significant losses to fish, resident wildlife and waterfowl habitats. The ineffectiveness of existing systems to address these damages is graphically demonstrated by the fact that Arkansas has yet to receive the first acre of mitigation lands. Discussions center on system fallicies and possible solutions.

For purposes of a discussion of fish and wildlife mitigation it is appropriate to consider the prosaic definition of the word "mitigate" which, according to Webster, is "to mollify, to cause to become less harsh or hostile". Often "mitigation" is confused with replacement and the casual participant often and correctly fails to understand how a stream once inundated or channeled, or a wetland once drained and cleared, can be replaced, or in his vernacular, "mitigated". We accept the succinct definition and are content to (hopefully) lessen the severity of a given land or water management project's impacts on wildlife and fisheries resources.

Mitigatory efforts are however, as we shall see, often frustrated in bureaucratic chaos or, in some cases, simply dispatched without ceremony by powerful special interest groups. Sometimes a combination of the former and the latter approach is preferred but the machination is academic to the fact that as a practical matter, Arkansas has yet to receive realistic and tangible compensation for any of the more drastic habitat alterations which have occurred as a direct result of, or have been occasioned by, Federally-sponsored or financed water management projects. A brief examination of sequential events which may have promulgated a calloused attitude toward wildlife resources (or what is sometimes referred to as the "Bulldozer Syndrome") is a logical prelude to a discourse on mitigation matters.

America came into her full inheritance at an early, if somewhat tender age, emerging from her military conflicts as a global power of some eminence while achieving on the home front an era of equality, prosperity, opportunity and individual wealth seldom attained in the annals of the world's great civilizations. Notwithstanding the attributes of moral fiber, ingenuity and determination which characterized America's approach to some of her knottier international and domestic problems, a principal asset was the vast stores of natural resources, omnipresent and available in seemingly inexhaustible quantities. Wildlife resources were viewed in this context. A pioneer ethic prevailed which dictated the conquering of the wilderness, the draining of the swamp, the clearing of the land - a cut-out-get-out philosophy which has become increasingly inappropriate in contemporary times.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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The proceedings of the Smithsonian's annual Symposium in 1967 touched on this concept in "Pastoral Ideals and City Troubles" with the observation that, "In America during the 19th Century, the image of a green garden, a rural society of peace and contentment, became a dominant emblem of National aspirations. Only the most astute grasped the contradition between the kind of society Americans said they wanted and the kind they were actually creating.

"One of the principles suggested by literary pastoralism is the importance of diversity in physical settings - the need to preserve the distinctness of the three spheres of our environment: the city, the rural countryside and the wilderness. Our literature supports the idea that each of these performs an important role in our psychic economy and that quite apart from nostalgia, sentiment, or any narrow measures of utility, either economic or recreational, each offers indispensable satisfactions."

Environmental awareness and concern has been propounded by legislative fiat over the past decade with the growing realization that the frontiers have in fact been subdued, and continued and unchecked exploitation of remaining natural resources can rob this country of a diversity in physical setting that in many respects is far more relevant to posterity than the balance of one's fiscal account. Arkansas has reached this crossroad and decisions formed over the next few years may well determine the fate of vestiges of a once magnificent wildlife and fisheries resource base. The moment of these determinations is all too apparent in the face of current economic development proposals and thus far the impact of mitigatory measures has been negligible. Fish and wildlife mitigation will have come too late for much of Arkansas.

A State Game and Fish Commission occupies a unique vantage point in observing and evaluating factors which collectively contribute to the demise of environmental quality or, more appropriately, to the quality of living as measured in opportunities to escape the assaults that one's senses are subjected to with monotonous regularity in contemporary urban society. For those of us who appreciate and require the amenities that wild areas and wildlife resources provide, the necessity of maintaining a viable and diversified habitat base is all too obvious. Unfortunately in many areas of our State this effort is relegated to a salvage operation beyond the capabilities of a singular State Agency, and while attempts at fish and wildlife mitigation have been diligently pursued under the auspices of the Fish and Wildlife Coordination Act, the net results are depressing indeed. A case in point is the U. S. Corps of Engineers' St. Francis Basin Project in the Mississippi alluvial plain of eastern Arkansas. The events of record of the St. Francis Basin fish and wildlife mitigation proposal are as incredulous as they are disheartening; however, if there is a lesson to be learned from this experience, it is that "mitigation is as mitigation does."

The St. Francis River Basin encompasses some 8,400 sq. miles in Arkansas and Missouri traversing longitudinally some 215 miles of Mississippi River delta and extending horizontally some 53 miles at its widest point. These lowlands were originally annexed in 1803 with the Louisiana Purchase and were parcelled to the State under the Swamp Act of 1850 with the stipulation that all land receipts be deployed in an extensive (if somewhat visionary for the times) reclamation effort. Subsequently, considerable levee and drainage works began to alter the courses of natural streams in the Basin and forested lands were cleared and subjugated to early agricultural endeavors.

In 1904 a St. Francis Valley Drainage Association was formed with the ostensible purpose of providing interior flood control and drainage along the main levees of the Mississippi River and seven years later the genesus of a comprehensive drainage plan appeared with the advent of a U. S. Department of Agriculture report which advocated the construction of floodways and an extensive system of ditches to augment swampland reclamation objectives.

The Corps of Engineers intervened in 1929 with the publication of a St. Francis Basin Report which appeared as House Document No. 159, 71st Congress. Although a substantial portion of the 1911 (U.S.D.A.) plan had been implemented by this time, annual interior flooding continued on a copious scale and subsequent Flood Control Acts in 1936 and 1946 bolstered earlier drainage efforts with substantive appropriations which removed all requirements for local cooperation except levee maintenance.

Hunters and fishermen by the 1950's were beginning to perceive the insideous effects of these massive drainage efforts on wildlife and fisheries resources and in November of 1958 the Arkansas Game and Fish Commission and the (then) Bureau of Sport Fisheries and Wildlife, participated in a joint study and report destined to qualify the astuteness of the recently amended Fish and Wildlife Coordination Act and, perhaps, the Corps' good intentions.

By the late 1950's aquatic and terrestrial habitat had been severely decimated in the St. Francis Basin and losses were accruing at a heretofore unprecedented rate with the advent of modern earth-moving and farming machinery. The Bureau report noted drastically reduced habitats in the Basin and found remnant resources to be "in the nature of a critical asset." Gigantic machines had raced across the alluvial valley erasing large swaths of the more conspicuous floral asset, streams and natural overflow lakes had become choked with silt and sediments to the extent that native fisheries were virtually obliterated, and drainage activities had reduced the extent and duration of overbank flooding on State Wildlife Management Areas and National Refuges to the detriment of waterfowl use on these important wintering grounds. The most obvious and perhaps the most tragic loss has been the destruction of the once magnificent delta hardwood resource with its rich diversity of fauna.

Extensive additional flood control and drainage schemes proposed by the Corps of Engineers would further reduce the effectiveness of State and Federal wildlife facilities and assure a continued and well-coordinated assault on vestigal stream resources and privately-owned wetlands. Projected wildlife and fisheries losses were duly quantified and capitalized according to prevailing procedures (Conservative indeed by today's standards!) and mitigation recommendations were set forth for inclusion as integral features of the Mississippi River and Tributaries Projects in accordance with relevant provisions of the Fish and Wildlife Coordination Act. Recommendations included several structural measures, some of which were eventually sponsored and funded by the Arkansas Game and Fish Commission (not mitigation!) and the acquisition in fee title of four areas comprising some 75,500 acres, a realistic and, to our way of thinking, responsible approach for mitigating at least a modest portion of the devestation which had occurred or would be occasioned over the 8,400 square mile basin.

The first rub came with a Corps "economic evaluation" of the mitigation proposal which deleted some 62,000 acres from the prescribed total, leaving 13,500 acres to be acquired at a location known as the Johnson Lake-Mud Lake site in the lower basin. Over two years lapsed before this recommendation gained the concurrence of the Chief of Engineers and another three years transpired before the measure was adopted in the Flood Control Act of 1965. Funds were made available for the acquisition of the Johnson Lake-Mud Lake site in 1968, some ten years after the original B.S.F.W. report and recommendation and to no-one's astonishment, it was discovered that most of the lands had been cleared for intensive agricultural use and were no longer suitable for wildlife conservation purposes. This called for a recap of studies and recommendations which spanned another four years after which the updated USFWS report and substitute acquisition recommendation was judged by the District Engineer to be lacking in fundamental bureaucratic sophistication to the extent that further study revisions were required. The recommendation went to Washington in mid-1973.

Necessary authority to acquire substitute lands was granted in Section 42 of the Water Resources Development Act of 1974 and that same year a Real Estate Design Memorandum was approved by the Chief of Engineers for 11,900 acres in the extreme lower basin at a location referred to locally as "Stumpy Point". Morale actually soared in the wildlife community as the Corps' Real Estate people scurried about obtaining appraisals and seeking preliminary title evidence for the recommended mitigation tract. Our elation was soon curtailed by a 1975 letter from Washington which informed the District Corps Office that authorities were being sought for acquisition by "preservation easements" and that the Corps should withhold action for purchases in the Stumpy Point area (no fee simple lands). Without launching a prolonged diatribe on the more objectionable aspects of the "preservation easement", suffice it to say that the easement offered nothing of substance for fish and wildlife mitigation and was entirely unacceptable to the Arkansas Game and Fish Commission.

Following another series of skirmishes and machinations, an agreement was reached whereby the Corps would proceed with fee simple purchases in the St. Francis Basin where lands were available from willing sellers. Notwithstanding the obvious improbability of being able to assemble a contiguous and manageable unit from such a hodge podge acquisition program, concerned agencies set about the task of soliciting landowners who were willing to part with certain parcels of lands that might be suitable for wildlife management purposes. Needless to say, a large percentage of lands offered were those which couldn't be feasibly deployed to any higher and better use. They were, in a word, wet! - - - too wet in many cases to accomodate a flora which would support the standard variety of indigenous wildlife forms. In the ensuing years the U. S. Corps of Engineers performed admirably in the compilation of a package designed to meet the total acreage requirements under the more recent constraints and fortunately, substantial acreages of swamplands were available adjacent to the St. Francis Sunk Lands Wildlife Management Area (a most fitting name for this particular area).

The mechanism for the transfer of these lands to the State is as yet untested; however, assuming all goes well in this regard, we will have some 12,500 acres (1,000 acres ended up in Missouri) of mediocre habitat (in a checkerboard pattern) to compensate the essential negation of most of the St. Francis Basin as a viable wildlife production area in the State of Arkansas. Bear in mind this is one project in one basin in an almost totally devestated 15,000 square mile Arkansas delta which may receive this token mitigation. Most remaining delta lands outside of Federal and State Refuges and Wildlife Management Areas have since acquired the New Look and Arkansas has yet to receive the first acre of mitigation land. The situation in eastern Arkansas thus far dramatically portrays gross deficiencies and inconsistencies in the "mitigation" system or perhaps more appropriately, the Fish and Wildlife Coordination Act.

The most feasible alternative to stolid acceptance of unilaterally processed Federal water management schemes would seem to be reform of the 1958 Fish and Wildlife Coordination Act. The Act as we know it has actually been on hand for over forty years (with amendments by the Congress in 1946 and 1958) with the ostensible purpose of assuring that fish and wildlife resources receive "equal consideration" with other project objectives in water resource developments and although the Act amply reflects the good intentions of its authors, it has consistently been ineffectual in protecting and conserving wildlife and fisheries habitats and has yet to salvage anything of value in the wake of massive Federally-sponsored water management projects in Arkansas. These deficiencies have been documented and decried by private and governmental elements within the conservation community and attempts at rectification have included introduction of strengthening amendments and petitions for revision of agency regulations under existing authorities (FWCA and NEPA).

A National Symposium on the Conservation and Enhancement of Fish and Wildlife in the National Water Resources Program held in Washington, D. C. in 1970 brought together 22 conservation organizations, 40 individual States (and some of the most sagacious minds in the business) and as a result of this Conference, a National Coordinating Committee was established to review policy positions on fish and wildlife conservation in the National water resources program. Subsequent regional conferences and publication of the "Action Report" promised to funnel Fish and Wildlife Agencies into the mainstream of water management planning with legislative recommendations which would bolster the FWCA through amendments designed to: (1) establish full resource conservation as a planning objective; (2) prohibit use of a monetary estimate of project losses to fish and wildlife as a limit on project expenditures for mitigation measures; (3) require that the recommendations of the BSF&W and the State fish and wildlife agency be set forth explicitly in project authorization documents, and where disagreement exists, require the construction agency to give equal consideration to wildlife objectives and fully justify final decisions; (4) require that authorized fish and wildlife measures (and this is most significant!) including land acquisition, be accomplished in a timely fashion in relation to other project features, i.e., land acquisition for fish and wildlife mitigation should be accomplished commensurate with or, in some cases, prior to, acquisition of lands required for project works. Added flexibility would also permit the addition of fish and wildlife features found to be needed after completion of the project; (5) include the TVA, AEC and the SCS under the purview of the Coordination Act; and (6) clearly define such terms as "conservation", "preservation","compensation", "mitigation", etc.

The National Coordinating Committee proceeded to conduct cooperative reviews of existing programs with an overview of system shortcomings in regard to fish and wildlife resources and in 1973, some of the recommended language appeared as H.R.10651, 93rd Congress, 1st Session, more popularly known as the "Reuss Amendments". While the Reuss amendments and similar legislation developed during the 93rd Congress were staunchly defended by conservation interests during hearings before the House Committee on Merchant Marine and Fisheries (Subcommittee on Fisheries and Wildlife Conservation and the Environment), our efforts were effectively obviated by opposition factions and the merits of our proposals in relation to the excellent work of the National Coordinating Committee were at best, academic.

The Corps paved the way for opposition interests at House hearings by testifying that the status quo was more than satisfactory for conserving wildlife resources and furthermore wildlife agencies should use their own funds in evaluating impacts of water projects. Speaking for the Corps, the Director of Civil Works even proposed that a time limit be imposed on comment periods allocated wildlife agencies under coordination sections of the Act and S.C.S., T.V.A., A.E.C. and F.P.C. followed suit with similar disparaging testimonials. These same big league adversaries have acted in a timely and competent manner and with apparent success on those other occasions when F.W.C.A. reform measures have been proposed. These are people who obviously know their way around Washington!

Current legislative goals predicated on the Action Report and ancillary work by concerned agencies, organizations and individuals leave little room for compromise. These objectives have been meticulously and systematically composed and primarily embody those elements which are actually conspicuous by their absence in the 1958 Act. Perhaps in the wildlife community the same professionalism and acuity which has been so instrumental in developing sound and incontestable recommendations has inhibited a headlong plunge into the arenas of activism where legislative proposals become realities.

Dr. Leslie Glasco, one of the more esteemed mentors of the wildlife profession, in his closing remarks at the 1970 National Symposium on the Conservation and Enhancement of Fish and Wildlife, stressed the criticality of the ensuing decade to remaining habitats and opined that wildlife professionals are "too permissive, too complacent, and too willing to compromise". These observations seem apropos in the mitigation dilemma.

Mitigation - We Won't Settle for Less[1]

Eugene S. Dziedzic and Wendell Oliver[2]

Abstract.--Major developments - especially hydro - have eroded fish and wildlife habitats in Washington State. Game Department has used many strategies and legal tools to reduce or mitigate losses. Federal and private hydro and irrigation projects, studies, and mitigation case histories are included. Deficiencies in current attitudes, procedures, and laws, and recommendations are discussed.

"Winning isn't everything - it's the only thing." Vince Lombardi stressed this philosophy to his NFL champion Green Bay Packers - and they won!

Mr. Lombardi would be perplexed if he were here and learned the rules of the mitigation "game" we are discussing at this symposium.

"Mitigation be damned," he would thunder, "that's admitting defeat before the game starts. Anyone with that attitude won't play on my team - I have no place for a loser."

We agree that acceptance of the mitigation concept is tantamount to admitting defeat before the process starts. Is it any wonder, then, that when we look at our record we see we have lost so much and gained so little?

Equity can only come about where sponsors of destructive projects replace the numbers and kinds of fish and wildlife which will be lost. We still won't meet Lombardi's standard, but at least we would have a fair chance for a tie game by insisting on a different set of rules.

I am convinced that some of our adversaries wonder why we make it so easy for them in this game we play. They are dedicated to their cause and they usually get their way - because they play to win. It's not their fault when we are too naive or less aggressive than we should be. I am convinced, again, that many in development agencies know we are getting less compensation than we should - but it's not their responsibility to score points for us. If we assert ourselves, and we must, I think we will be surprised by the allies we will gain within development agencies. But, we will gain their support only when we change from acting like losers - when we show them we deserve to win - when we earn their respect.

What must we do to reverse the present trend - to earn respect - to become winners? As a first step, I suggest we find a cure for a disease I term "mitigation psychosis" (MP). This MP disease is endemic in fish and wildlife agencies, characterized by a lethargy which allows us to be content with managing what is left rather than with assertively planning for the future. MP victims love to go to interagency coordination meetings where they can think about retirement rather than fight what they think is a losing battle. They have a reputation for being reasonable negotiators - "good guys" who have learned to compromise. They are skilled in the use of jargon - especially such terms as "trade-off," "the national interest," "energy crisis," and "balancing environmental losses with economic gain." Most damaging is their ability to live with being losers.

Some of my colleagues may resent what I've just said. I hope so. Others may wonder if I will have something constructive to offer. Again - I hope so.

I believe the single, most important thing necessary to solve the problems which led to this symposium is a change in attitude. And I don't mean the attitude of the Corps, Bureau of Reclamation, SCS, or Congress. To quote a comic-page philosopher - "We have seen the enemy - and it is us." Fish and wildlife professionals must become winners instead of losers.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Chief, Habitat Management Division, and Applied Research Team Leader, respectively, Washington State Department of Game, Olympia, Washington.

How do we do this? First, we must change direction - become dedicated to habitat protection rather than obsessed with only managing the animals which are left. We must find and use the very best people in the struggle to save and improve habitat for wildlife. We must find the time and money to acquire facts and use them effectively. We must gain credibility and respect in our negotiations with development agencies.

Finally, we must remember who we are and what we represent. We are (or should be) the professionals who are charged with preserving, protecting, and perpetuating wildlife. Citizens concerned about these resources rightfully expect us to represent their interests. Most important, our only reason for being in this profession is to speak for a silent constituency - the wild animals who are most directly affected by our competence; they have no other recourse. We must truly recognize this role and measure up to professional standards upon which they depend for their welfare and survival.

By contemporary standards, Washington Department of Game has been relatively successful achieving fish and wildlife mitigation - that is if you equate success with reversing the downward trends of fish and wildlife populations in our state.

This is what we have gained - through use of state and federal laws, diligence, and moral persuasion. Present practice in Washington State is to require that the developer:

1) fund fish and wildlife inventories both before and after project;
2) fund acquisition of suitable replacement habitat;
3) fund development and management of replacement habitat;
4) fund interim mitigation measures until managed habitat becomes productive; and
5) fund on-going evaluation of mitigation progress.

But, we found that these standards are inadequate - they do not compensate nor replace; we need better tools and strategies to preserve fish and wildlife for future generations.

We propose that states reevaluate their attitudes toward fish and wildlife mitigation. We have identified ten issues which we find significantly impede the compensation process. We propose the following:

Issue #1: State fish and wildlife agencies are being overwhelmed by development pressures on habitat. The burden of providing "last-minute" environmental assessments is staggering - and the result of our impact analysis is usually "steam-rollered" after great sums of development money have been spent. A few fish or birds are seldom allowed to impede this progress.

Solution: State fish and wildlife agencies must be brought into the process at the earliest planning phase - not late in the process when their decisions carry little weight.

Issue #2: Most state agencies are not adequately staffed to make site specific impact analyses. When we provide inadequate information, fish and wildlife are vulnerable to development pressures - compromise becomes the only alternative. On the other hand, transfer funds to assess fish and wildlife impacts are available to federal agencies. Unfortunately, these funds are not available to acquire hard data from state agencies who are directly responsible for fish and wildlife.

Solution: Federal transfer funds for assessment of resident fish and wildlife should pass directly to the responsible state agencies.

Issue #3: The technology to replace lost fish and wildlife is inadequate and, generally, untested. (We must learn how to replace two deer in the space now producing one.) Aside from hatcheries and game farms, we have largely depended upon mother nature or managers of farms or ranges to give us information we need.

Solution: Colleges, universities, and resource agencies must develop methods to replace fish and wildlife. A federal extension program should be established to provide fish and wildlife the same services now provided to agriculture.

Issue #4: Fish and wildlife replacement efforts are often subjected to arbitrary cost ceilings which reduce the effectiveness of proposed measures. For example, we are faced with cutbacks in Snake River compensation efforts before a shrub has been planted or a chukar is hatched.

Solution: States must insist that fish and wildlife compensation levels be guided by biology rather than budgets!

Issue #5: Resource and development agencies tend to forget replacement facilities once agreements have been reached. Recent evaluation of some mitigation sites in Washington found that we are not successfully superimposing new wildlife populations on top of existing wildlife. We also found that mitigation sites often become targets for conflicting developments, that is -- power lines, irrigation pumping plants, gravel removal, and general recreation.

Solution: On-going evaluation of fish and wildlife facilities designed to replace losses is essential for their success. Better protection of these facilities, as mandated by the Fish and Wildlife Coordination Act, is needed. We insist evaluation and protection are construction agency responsibilies.

Issue #6: Resident fish and wildlife (in contrast to migratory species) generally get "shortchanged" in impact assessments and replacement proposals. Why do we allow this? We cannot expect zealous commitment to protection of resident species if we delegate this authority to federal agencies. In the Pacific Northwest, we have numerous federal agencies engrossed in the fate of anadromous fish. This causes duplication of research efforts and dollars at the expense of resident species.

Solution: Federal agencies and intra-agencies should sort out their respective areas of responsibility so other impacted species get the attention they need. States must intensify their effort to preserve resident fish and wildlife, otherwise it will not be done.

Issue #7: Timely compensation for fish and wildlife losses is imperative. When railroads, towns, highways, or private residences are impacted, relocation is provided before the fact. During the present drawn-out negotiation-mitigation process, fish and wildlife losses compound annually. The public loses while the developer saves money by delaying. This is not fair. Fish and wildlife compensation on water development projects is required by law. It does not intend that interim losses be suffered by the public.

Solution: Fish and wildlife deserve "relocation" benefits equal to those granted other impacted facilities. States must insist that habitat be replaced at the same time, or before, development takes place. Costs of replacing fish and wildlife should be considered at the time cost/benefit analysis for project authorization is calculated, and not used to judge levels of compensation.

Issue #8: The public is usually unaware of what is taking place during planning and study phases of development projects. The deserve to know the potential consequences of actions contemplanted by agencies representing them. Instead, sportsmen find out too late that there is too little left to fish or hunt. This happens because fish and wildlife agencies are often unaware of planning decisions that impact wildlife - or they simply choose to ignore "piecemeal" habitat losses. In Washington we lose more habitat at weekly meetings of county commissioners who administer zoning than our agency can restore in years.

Solution: It is the responsibility of agencies to fully inform the public of "tradeoffs" being made as a price for development. Public support of resource agency position is invaluable and must be cultivated. States must establish annual population levels of wildlife which will be maintained as a public trust.

Issue #9: The economic values now assigned to fish and wildlife are inadequate and inappropriate. They do not accurately portray impacts on quality of life nor the incentive provided for major, non-polluting recreation industry. Fish and wildlife are taken for granted and, generally, undervalued. Economists have messed with various techniques to value fish and wildlife commodities, but they cannot agree upon nor recommend a technique for us to use. Maintenance costs of remaining whooping cranes are available, but what would it cost to replace them?

Solution: We must develop and accept an economic valuation system for fish and wildlife - based on replacement costs.

Issue #10: While progress has been made to protect the environment and its fish and wildlife inhabitants, the process still allows most of the culprits to get away -- scot-free! Too many federal and state agencies, and federal subsidy programs, are exempt from protecting fish and wildlife. Illustrations are many -- The Department of Agriculture somehow avoids the EIS process. Their programs have subsidized wide-scale drainage in Washington which in some areas has led to marked decline in upland birds over the past 20 years. Interstate highways cover about thirty-six acres of habitat per mile without compensation. Urban development uses up about 100 acres of habitat for every 1000 new residents. And while fishery interests, both while and Indian, are striving for restoration of salmon -- irrigation projects on Reservations claim immunity from water quality and hydraulic standards that are designed to protect fish life.

Solution: State agencies have the obligation to close loopholes and secure legal protection for resident fish and wildlife, particularly where public funds are involved in activities that lead to habitat destruction. The Fish and Wildlife Coordination Act must be expanded to cover activities of all federal agencies. States must have similar protection to cover activities funded by state budgets.

CONCLUSIONS

All signs point to a federal takeover of state's rights. Federal agencies in Washington State have more biologists on the payroll than Washington Department of Game --but do not bear on shred of direct responsibility to Washington's residents to protect their fish and wildlife resources. (We hold public hearings every time we enter a coffee shop) If we are content to abrogate state authority to federal agencies, overlook piecemeal loss of habitat, fail to declare specific levels of wildlife that will be maintained for our public's use, then we deserve nothing better than mitigation - rather than full replacement.

Mitigation as now practiced is a "ripoff". In effect, it justifies the destruction of public resources with public funds. Generally, federal water development projects generate large profits in the private sector. These benefits are measured by national or international markets - but state residents suffer the environmental costs. Those benefiting from habitat destruction should be paying the price of fish and wildlife replacement - not haphazard mitigation.

In Washington State, fish and wildlife "belong to all the people". State residents are being cheated by every project that does not replace resources it destroys. The only acceptable alternatives are proper evaluation of true and complete social costs, or immediate and complete replacement of fish and wildlife in numbers and kinds. Then the action may be fair and equitable.

We have directed our remarks to state agencies. But now we include federal agencies in our proposals -- get rid of biologists who are old enough to remember the "good old days".

Habitat Mitigation in Indiana's Authorized Channelization Projects[1]

Robin F. Knox[2] and James D. McCall[3]

Abstract.--Since 1970 construction has been completed on approximately 30 miles of PL-566 channels scattered throughout Indiana in 5 separate projects. Since 1973 a joint Memorandum of Understanding between the SCS, IDNR, and USFWS has fostered development and implementation of project features designed and installed to protect or mitigate losses of fish, wildlife and riparian habitats. Successful implementation of such features has expanded their use to channel modification caused by highway bridge construction and legal county drain maintenance.

INTRODUCTION

Since 1967, it has been the policy of the Soil Conservation Service (SCS) in Indiana to plan watershed projects with interdisciplinary input from several federal and state agencies. In Indiana, the biology team has representatives from the Indiana Department of Natural Resources, Division of Fish and Wildlife (IDNR), the U.S. Fish and Wildlife Service (USFWS) and the SCS.

Since 1973, a joint Memorandum of Understanding between the three agencies has fostered development and implementation of project features designed and installed to protect, or mitigate losses of fish, wildlife and riparian habitats. In addition, the new channel modification guidelines recently implemented by the SCS and FWS help to insure that the three agencies involved work together to accomplish common goals concerning fish and wildlife resources.

A spirit of cooperation is necessary when the following facts are considered. Sixty percent of the land use in Indiana is agricultural. Sixty percent of the cropland in the state has water related problems. Excess wetness is one of the limiting factors in crop production. To further emphasize the problem we are dealing with, it is important to note that county governments have worked on over 36,000 miles of legal drains for the purpose of drainage. Many of these drains are creeks or streams which were dredged with little or no consideration for fish and wildlife needs.

Since 1970, the SCS has assisted local groups in completing about 30 miles of channel work for flood damage reduction and drainage. Unlike the channels designed twenty years ago, with no regard for fish and wildlife habitat, the multiagency approach has resulted in channel projects with features designed to minimize impact and mitigate losses.

BIOLOGICAL REVIEW

Prior to the start of most projects, the multiagency biology team conducts field inspections of project areas to assess the fish and wildlife resource and identify any critical or sensitive habitats. The usefulness of this approach has been demonstrated in two areas. In the Prairie Creek-Vigo County Project, a 65-acre wet woodland adjacent to the stream was deemed to merit special consideration. Soil testing indicated that the channel could be cleaned out along one side of the woodland without draining the adjacent wetland habitat. Before the plan was completed, the sponsors purchased the wooded swamp to guarantee its legal protection for the life of the project. Physical protection of the area included levee construction and a stabilized tlet for passage of fish and other aquatic una. Planning, installation and management ases were coordinated to ensure the preservaon of the riparian wetland habitat.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 17-20, 1979.

[2] Nongame Aquatic Specialist, Colorado Division of Wildlife, Denver, Colorado.

[3] SCS State Biologist, USDA Soil Conservation Service, Indianapolis, Indiana.

The Upper Big Blue River Project, located east-central Indiana, was an old project that s recently reactivated. The original plan lled for channel enlargement to reduce flood mage to cropland. In 1977, during intensive ological surveys initiated by the SCS, a rsery colony of over 50 endangered Indiana ts (Myotis sodalis) was located in a dead ee along the bank on the proposed construcon side. Consultation with the U.S. Fish and ldlife Service, the Department of Natural sources and Earlham College endangered species ecialists resulted in a change of plans. The oposed enlargement of the lower 5 miles of annel was changed to a plan for drift and bris removal. The new plan would not adrsely affect the riparian habitat where the rsery colony tree was found.

DEBRIS REMOVAL

Drift and debris removal probably is the thod of channel improvement that has the ast impact on fish and wildlife habitats. It utilized wherever and whenever possible, in eference to other methods of channel work. ve miles of the lower end of the Middle Fork derson River in southern Indiana had adequate pth and width, but flows were restricted by llen trees and logjams. The multiagency team rked the hazardous trees and other debris to removed. To minimize damage to living trees, e contract for work specified that only hand ols and small machinery be used. A small boat d log skidder proved to be effective in the moval of logjams. Fallen trees were skidded onto the bank and lodged, tied down or buried that they would not float back into the chanl. The completed job was aesthetically easing and moved the water as intended. The oject was considered a success by all conrned, including local landowners, agency spealists and other observers (fig. 1).

ROCK FISHWAY

The Rock Creek-Cass Co. Watershed flood otection channel in north central Indiana was iginally constructed with a 65-foot wide flat ttom on solid limestone.

To offset the losses of fishery habitat used by modifying this channel, a fishway of ols and riffles was constructed. The fishway s designed by the IDNR biologists and SCS ecialists working together with the local sidents. The pools were blasted or ripped 2 1/2 to 4 feet deep and the riffles about 6 inches deep.

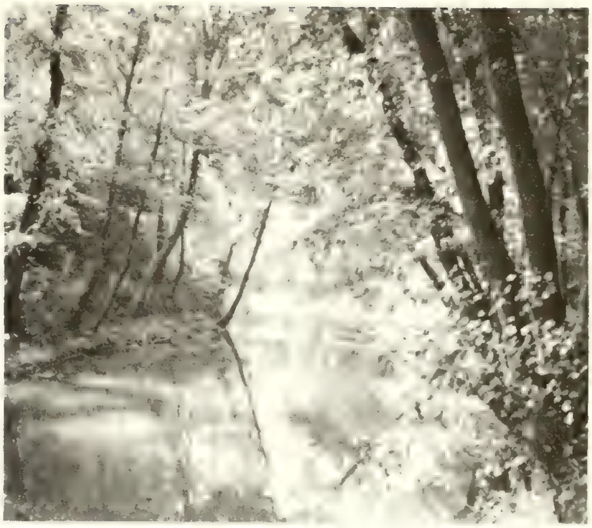


Figure 1.--Completed channel work involving drift and debris removal on the Middle Fork of Anderson River in southern Indiana.

Post-construction field studies have shown that use of the fishway is much better than expected. Twenty-three species of fish were found by biologists in this man-made fishway one year after completion. These species included smallmouth bass, rock bass, longear sunfish, white sucker and several species of darters and minnows that serve as forage for game fish. Only 16 species were found in the natural channel upstream from the constructed fishway. In the 3 years following, species numbers in the constructed fishway totalled 23, 22, and 23 respectively.

Twenty-five species of fish were captured by electro-sampling during August 1978, 5 years after completion of the constructed fishway. Fish abundance generally was greater in 1978 than in previous years. Smallmouth bass ranging from 3 inches to 20 inches were found this year. The greater abundance of fish in the fishway in 1978 may have been due to construction activities upstream.

Concentration of the flow of water into the fishway has allowed the overflow portion of the channel to become naturally revegetated. The growth is starting to shade the stream and attract numerous species of wildlife.

ONE-SIDED CONSTRUCTION

Prior to the time when fish and wildlife habitats were seriously considered, most channel construction resulted in damage to both banks of a stream. Presently, when channelization is planned, the construction activity is conducted from only one side and the route follows existing channel alignment. The side to be disturbed is determined after a series of field investigations. Whenever possible, the disturbed side is that which offers the least amount of habitat for resident species. Wherever possible, large trees on the construction side are left standing. Protection of vegetation along one bank has proved to be a valuable tool in preserving some of the integrity of the natural channel, providing a source for natural revegetation, and maintaining some of the riparian habitat.

Revegetation of the constructed bank takes place as soon as the spoil is shaped. There is an immediate seeding with a grass-legume mixture to stabilize the soil, and a later planting of woody and herbaceous species to mitigate the loss of native vegetation. Species used in several projects to date include: alder, sycamore, walnut, tulip poplar, white ash, autumn olive, gray dogwood, Washington hawthorn, red bud, and several types of lespedeza.

In most areas, the spoil material is relatively fertile. Heavy growths of planted and natural woody and herbaceous vegetation cover the spoil in one growing season. The vegetative cover acts as a filter strip to help keep sediment out of the water. Within five years after a project has been completed, the channel often has returned to a semi-natural state. Buck Creek (fig. 2), in the Upper Big Blue River Watershed, had excellent vegetative regrowth on the constructed side after only one year.

The permanent easements needed for construction and revegetation often lead to a wider zone of riparian growth than was present before construction. To prevent encroachment on these areas by farmers, vegetative markers are placed between new plantings and the row crops. The markers are made of 2-inch galvanized steel pipe anchored in concrete. These markers have been respected in most projects to date.

RIP-RAP DEFLECTORS

In Indiana, the majority of completed projects have required rip-rap deflectors with excavated fishpools to compensate for the loss of aquatic habitat. The number of fishpools and deflectors per mile of channel is based on preconstruction inventories to determine the quality of the aquatic habitat and what species are present. The deflectors are composed of rip-rap or rip-rap with logs, depending on the nature of the stream. Pools below the deflectors are excavated 3 to 4 feet deep (fig. 3).

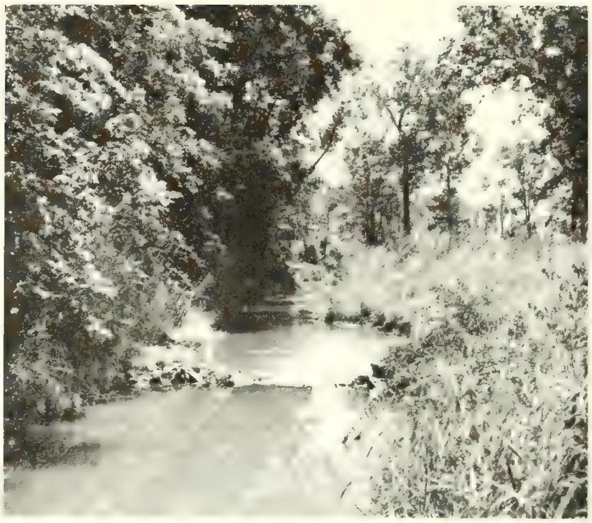


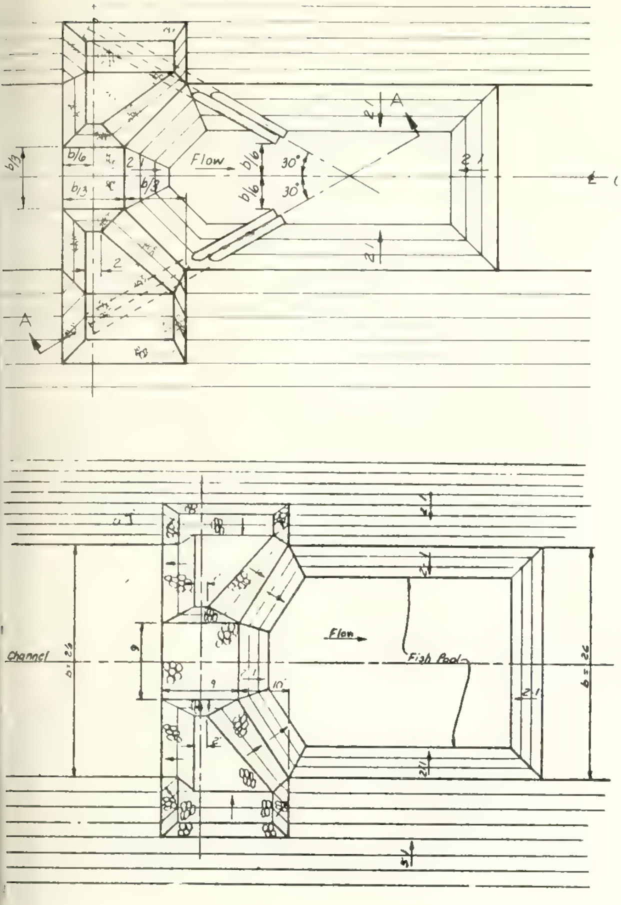
Figure 2.--One year after dragline cleanout, trees on undisturbed side provide shade for the stream, while mitigative plantings on th disturbed bank show partial restoration of riparian habitat.

Annual monitoring of Buck Creek in East-central Indiana, Rock Creek in North-east Indiana and Prairie Creek in Western Indiana ha shown that the fishpools are self-maintaining and are supporting populations of game fish species.

OTHER FEATURES

Buck Creek in the Upper Big Blue River Watershed provided a chance to solve a polluti problem of a livestock feedlot. Following procurement of easements for construction, the feedlot was fenced and a watering access site for the cattle was constructed. After bank reconstruction and revegetation, the channel in this area now supports good bank vegetation an improved water quality. Without the project, is highly doubtful that the past problem would have been solved.

One of the newer techniques that the mult agency team is using to improve habitat in present projects is that of leaving excavated spo roughly piled on the constructed bank. When the rough spoil is intermixed with downed timb and revegetated, a larger variety of habitats develop for those wildlife species common to t riparian areas. Prairie Creek-Vigo County, in West-central Indiana is the first SCS project where this technique is being used. Early



igure 3.--Typical deflectors with fishpools
constructed in SCS projects in Indiana.

ndications are that these areas are being uti-
ized by burrowing species within 6 months of
evegetation. Future monitoring will be needed
assess this method of mitigation.

OTHER APPLICATIONS

The various mitigative measures previously
scribed have proved to be useful in protecting
her riparian habitats in Indiana. Based on
perience gained from installation of struc-
res in the SCS projects, the Indiana Division
Fish and Wildlife has expanded their use to
her types of development. In those areas
ere the Department of Natural Resources ex-
cises Permit and/or other legal jurisdiction,
e installation of sediment-traps, rip-rap
shpool deflectors, and one-sided channel work
s become standard practice. The combined
rmit Applications in Indiana for highway
idge construction, pipeline, powerline or
her stream crossings, and legal drain con-
ruction, represent development that could adversely impact 25 to 35 miles of channel and associated riparian habitats per year. In many of the heavily farmed regions of the state, these riparian areas provide the only woody habitat for many of our wildlife species.

Wherever feasible, the riparian habitats to be affected by development are field inspected and specific mitigative features are then made part of the Permit Approval procedures. The greatest use of SCS designed structures has been in highway bridge construction and legal drain maintenance. Although it has been difficult for some engineers and drainage boards to accept, protection of riparian habitats is an active policy of the Division of Fish and Wildlife.

The mitigative procedures developed during Soil Conservation Service planning have provided us with additional tools to insure the preservation and maintenance of Indiana's riparian habitat.

SUMMARY

In summary, techniques being used in Indiana to protect riparian vegetation and to offset or reduce the adverse impacts of watershed projects on water quality, fish and wildlife habitat, and visual quality of the stream corridor, include:

1. Installation of sediment traps to prevent sediment from leaving the construction site.
2. Construction on only one side of the stream channel.
3. Removal of waterway obstructions with handtool and small equipment.
4. Construction of continuous pool-riffle fish habitat in bedrock.
5. Installation of fish pools with deflectors and constructed riffles in earth sections.
6. Woody and herbaceous vegetation plantings.
7. Maintenance of shade over water.
8. Wetland acquisition.
9. Use of fencing and vegetation markers.

Channelization in Colorado — Past, Present and Future[1]

Eddie Kochman[2]

Abstract.--Recognizing the need for control of stream channelization, the Colorado legislature in 1969 passed the Stream Protection Act, 33-5-101, C.R.S., 1973. The law gave control over state agencies who proposed channelization or other projects that would modify aquatic habitat within streams and rivers. The Division of Wildlife has developed specific organizational procedures to carry out the intent of the law including mitigation techniques.

Stream and river channelization has been of great concern to biologists and resource managers within Colorado for over 80 years. It is estimated that channelization has impacted at least one-third of the state's coldwater trout streams. Colorado has approximately 8,700 miles of trout waters ranging in size from small, high elevation streams to large, blue-ribbon trout rivers such as the Roaring Fork and South Platte. The impact of channelization has touched many of these streams and rivers with varying degrees of effects on their capabilities to produce trout and recreational opportunity. An evaluation showed that since 1950, over 3,000 miles of the state's trout waters were in some way influenced by channelization and associated impacts such as pollution. In certain streams, the results of channelization have and will continue to remain a constant detriment to the trout fishery. In others, a slow improvement has resulted over the years but there still remains evidence of indiscriminate channelization. In the future, with increased population growth and development, channelization poses an even greater threat to trout streams in Colorado and other western states.

Recognizing channelization to be a major threat to the state's trout streams, the Colorado Game, Fish and Parks Department, now Division of Wildlife (DOW), in 1969 was finally successful in convincing the legislature to pass a law for protection of fishing streams from channelization and associated impacts. Previous attempts were made prior to 1969 but were defeated entirely by outside lobbyists opposed to any state control over channelization. As originally written, the law gave control ove all sources of channelization including highway construction, land development, water projects and mining. Unfortunately, strong lobbying efforts did defeat the original intent of the bill and it was amended to include control over only "agencies of the state." As passed, the law did give control over state agencies respor sible for highway construction. A subsequent Attorney General's opinion stated that control also existed over individual counties as "agencies of the state." While the law did not pass as originally written, it was still a majc accomplishment to finally have legislation whic gave some control over channelization and associated impact resulting from the actions of other state agencies and particularly from highway construction.

Let me now briefly summarize some of the more important points in this law as it was passed.

1. It was declared to be a policy of Coloradc that fishing streams within the state are to be "protected and preserved from the actions of any state agency." Outside sources such as mining and water project development were omitted.
2. A provision in the law requires all state agencies who might modify, change o damage any stream, its banks or its tributaries shall notify the Commission of the Division of Wildlife "not less than 90 da prior to the date of commencement of the

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Fish Program Manager, Colorado Division of Wildlife, Denver, Colorado.

proposed project." It was emphasized that this notice shall include detailed plans as to the proposed project. Prior to passage of the law, there was usually no opportunity for advance review of projects.

3. After the Division of Wildlife reviews the proposed plans, it has a requirement to respond within 30 days. This requirement allows Division biologists to review the project and make whatever recommendations are necessary including provisions for mitigation or complete opposition to the entire project.
4. Based on the review process, the Division then notifies the appropriate state agency of its recommendations. If a recommendation is made against a proposed project which is not accepted by the appropriate state agency, then the entire matter is arbitrated by the Governor. I want to emphasize that many projects have been reviewed under the intent of this law and, since 1969, not one project has been arbitrated by the Governor. This speaks for the effectiveness of the review and mitigation process.

Since the passage of the Stream Protection , the DOW has developed a very positive pro-m with the appropriate state agencies and marily the Colorado Division of Highways H). Due to highway construction activities, DOH is the major state agency involved in nnelization or stream relocation activities. law was a major catalist in developing the gram.

The most important criteria within the law the requirement that when there is involvement h a stream, the state agency must notify the ision within 90 days of their action. This ification is not only limited to projects t will actually require stream relocation but o includes any work which will influence arian vegetation along the banks of a stream. ce the DOH was most involved as a state agency oint channel of communications has been devel-d between the Division of Wildlife and the ision of Highways. After the law was passed, DOW hired a fishery biologist to specifically rdinate with the DOH and other agencies. cific notification forms and channels of com-cation were also developed to expedite the ew and mitigation process.

Since the law was passed in 1969, over 270 vidual projects primarily involving highway struction have been jointly reviewed. This l represents nearly 130 miles of trout water hich the DOW had direct control in either ding channelization or mitigating its loss. llowed the Division in many cases to enhance t habitat through the construction of stream improvement devices and revegetation techniques. In some cases, channelization was completely avoided due to the development of better alternatives. In the majority of projects, necessary work was completed in a manner that either restored fish habitat to original conditions or actually enhanced habitat conditions.

After passage of the Stream Protection Act, the DOW developed policy statements regarding a review of proposed projects and official positions taken on stream relocation and channelization projects. These policy statements include:

1. No channelization, stream relocation or associated impact will be approved if it is determined through analysis that other feasible alternatives exist. Example: The stream section is proposed for relocation to accommodate realignment of curves along a major highway. The same realignment can be accomplished with the construction of bridges at key points on the stream. Construction of the bridges will not require extensive stream realignment and have proved to be cost effective.
2. If field analysis shows that the impact of the proposed action to the aquatic habitat is too great and mitigation is not feasible, then the action will be opposed. Example: In Colorado certain prime trout streams such as the Fryingpan and Roaring Fork Rivers should never be disturbed since aquatic habitat is optimum and mitigation is not feasible.
3. In all projects where channelization, stream relocation and associated work is undertaken, it is the objective of the DOW to restore post aquatic habitat conditions to as good or better than the original habitat conditions. Example: Certain streams lack optimum aquatic conditions such as inadequate pools or other resting areas. In these conditions, the Division develops a mitigation plan which would enhance habitat conditions by development of additional pools. In certain streams it is difficult to enhance conditions and in these cases the objective would be to assure that mitigation is adequate to at least maintain pre-habitat conditions.

The above policy statements are important in functioning with other state agencies that are involved in channelization projects. It is recognized that certain of the state's "blue-ribbon" trout fisheries are "hands off" regarding any project proposed and rechannelization.

Prior to final action by the DOW on any proposed project, a thorough biological analysis is completed designed to inventory existing conditions of habitat in the particular stream involved. These habitat conditions include the following:

1. Length of stream involved.
2. Average width of stream throughout project length.
3. Average water depth throughout the riffles and pools within project area.
4. Average water velocity and gradient thoughout the reach.
5. Ratio of pools to riffles throughout length of stream.

In addition to field inventory of habitat conditions, the fish population is also inventoried including species composition and age distribution. If it is determined that a wild and self maintaining trout population is present, emphasis is given to determining amount of spawning habitat that is available within the stream reach and how the proposed project will influence this habitat.

In addition to the emphasis placed on aquatic habitats, concern is also given to maintenance of riparian vegetation and natural channel esthetics. It has been the experience of the Division that unless the completed channel has a natural appearance, there will result adverse criticism from the fishermen as well as the public in general. Banks devoided of natural riparian vegetation do not present an acceptable appearance and in addition to adverse public reaction, the resulting impact can be increases in water temperature and loss of a critical link in the production of insects. It is my opinion that proper revegetation provisions have been very neglected in most mitigation plans involving channelization.

As a result of the importance of reestablishing riparian vegetation, the following criteria are required by the Division in stream relocation projects:

1. Maintain a minimum of 20-foot buffer zone of riparian vegetation along each stream bank. In a case of total stream relocation, this would require careful excavation through an area to maintain natural riparian vegetation on each bank. If this construction technique is not feasible, a revegetation plan must be included in the project that will revegetate each bank with selected species. This plan will include top soiling, fertilization and irrigation where necessary.
2. Meanders will be designed within a new channel to include confirmation similar to the pre-channel conditions. If increased meander is shown to be of benefit to aquatic habitat conditions and is feasible, it will be completed.
3. Stream banks along the new channel will either be stabilized by careful placement of rip-rap or allowed to undercut or conform to natural configuration.

Each of these criteria are important in constructing a final channel that is acceptable not only from the standpoint of aquatic habitat but also from the standpoint of natural estheti Agencies responsible for stream relocation, including the DOH, recognize the importance of th designing and construction channels with natura esthetics. Such mitigation is a minimal part o the project cost but yet pays big dividends fro the standpoint of public acceptance on enhancem of aquatic habitat.

It is important that each proposed stream relocation project be evaluated based in its specific conditions. For example, a project that involves only a small length of stream may not require extensive meandering, revegetation or stream improvement. Other streams, however, that are proposed for extensive stream relocati require very detailed pre-analysis work and wil likely require very extensive mitigation measur A recent example of such a major mitigation effort occurred on Tenmile Creek, tributary to th Blue River in Northwestern Colorado. Tenmile Creek flows through a very narrow canyon which was the corridor for construction of Interstate 70, a four-lane super highway. Like most narro canyons in Colorado through which a stream flow there was simply not room for the highway and t stream at certain points. The result was a nee to completely relocate over three miles of the old channel to make room for the four lanes of Interstate 70. On a cooperative tone, the DOW agreed to channelization which would eliminate the construction of two dangerous bridges. Construction of bridges would have eliminated the need for over one mile of channelization but would have resulted in icing and hazardous driving during the winter. By agreeing to the channelization, the DOW showed that motorist' safet as well as economics are considered in its analysis.

Prior to construction of the stream relocation, extensive planning work was completed with the objective of designing a new channel that would actually enhance aquatic habitat conditions. The opportunity to achieve this objective was realistic since the old channel o Tenmile Creek has been degraded for years by mining, pollution and past channelization. A habitat inventory showed that there was a need for an increase in the number of pools through the three-mile reach. A need also existed for increasing average water depth through both poo and riffles in order to improve resting, feed and spawning conditions. Much of the bank alo the old channel was lacking in riparian vegetation due to pollution as well as channelizati from past railroad and road construction. It

as the objective of the final design to im-
rove riparian vegetation along the new channel.
design team composed of fishery biologists,
resters, hydrologists and engineers developed
e final plan for the stream relocation. This
am proved very effective and it is recommended
at such an approach should be used in develop-
g mitigation plans on every major channeli-
tion project. To enhance habitat conditions,
cluding the development of pools, various de-
gns for log and rock check dams as well as log
d rock deflectors were developed. The width
the new channel was carefully designed to
intain optimum gradients, velocity and channel
pths. A revegetation plan included conditions
quiring top soiling, fertilization and careful
lection of riparian species of willows and
asses. Optimum meandering was included at
ery opportunity.

With the use of heavy front-end loaders,
ch of the new channel was actually revegetated
stantly with large clumps of willows from
arby sources and planted along the banks. In
dition to the aquatic habitat and revegetation,
ncern was also given to improving public access
ong the stream. This concern was not only for
shermen, but also for other recreational users,
luding bicyclists and hikers. As a result, a
ecial access trail will be constructed along
e stream.

The entire project cost over $500,000 to
mplete. A good portion of this total cost was
uired to construct the stream improvement de-
es and implement the revegetation program.
the money worth it? The answer is yes, from
concerned. The end result was the construc-
n of three miles of new stream that actually
an improvement over the old one. Results
far demonstrate the improvement in fish habitat with a resulting increase in fish populations and subsequent fishing opportunity.

We all realize that in not all cases is there an opportunity to fully mitigate habitat lost through channelization and stream modification projects. In Colorado, a great step was made with the preparation of the Stream Protection Act in helping us to deal with the problem. However, we are still largely at the mercy of outside sources such as mining, land development and water project development. As I emphasized, the Stream Protection Act only included control over other state agencies. The challenge still exists in the future to give the Division and the state of Colorado control over all sources of channelization and its associated impacts. It is the objective of the Division of Wildlife to continue to seek future legislation that will require inclusion of such sources within the Stream Protection Act. Since 1969, two efforts have been made to amend the Stream Protection Act to include needed control. Unfortunately due to heavy lobbying, the bill was defeated both times. We are confident that in the future the bill will be successfully amended. This confidence is based on the fact that the public is becoming increasingly knowledgeable on how priceless our remaining trout fisheries are and how important it is to provide the protection they deserve.

In summary, we in Colorado feel that great progress has been made in mitigating the loss suffered through channelization and stream relocations. Tenmile and many other projects are testimony that it is indeed possible to mitigate or actually enhance aquatic habitat. In the future we are confident that our success will continue.

Wildlife Damage Mitigation for California's State Water Project [1]

David E. Pelgen[2] and Robert C. Tharratt[3]

Abstract.--The State Water Project in Southern California impacted wildlife on more than 14,000 acres. Most of the impact was on lands purchased for the project; 15% was on National Forest System Land. Wildlife mitigation agreements have been based on both Federal and State laws. Discussion is included on relative success of the program and possible reasons for that success.

INTRODUCTION

The State of California has constructed a large State Water Project (SWP) covering two-thirds of the length of the State, which includes 25 dams and reservoirs, 684 miles of aqueducts and 30 powerplants and pumping plants. Construction began in 1960 and the initial major features were completed in 1973. The SWP is a multiple purpose project, with recreation and the enhancement of fish and wildlife among its purposes. State law provides for the preservation of pre-existing fish and wildlife resources in the construction and operation of the SWP.

Construction of the SWP started with the northern features of the Project and followed later in the central and southern portions of the State. Fishery preservation features were given major attention from the very first work on the SWP, and multi-million dollar fish hatcheries and fish screens are included as Project facilities. Wildlife resources did not receive the same emphasis in the 1960s, however, and only modest wildlife preservation features were included in the northern and central parts of the SWP.

Construction in Southern California was centered in the late 1960s and early 1970s, a time when interest and concern for environment values were growing rapidly. The National Environmental Policy Act of 1969 (NEPA) and California's Environmental Quality Act of 1970 (CEQA) were expressions of this concern. At this time it was obviously necessary that impa to wildlife habitat caused by inundation or co struction of structures, roads, etc., be considered and an appropriate program devised to mitigate damage to wildlife resources.

WILDLIFE STUDIES

Throughout the long planning process lead to development of the SWP, the Department of Water Resources (DWR), the agency responsible for planning and development of the SWP, has maintained close coordination with the Department of Fish and Game (DFG), the State's fish and wildlife agency. (This relationship, whic has resulted in fish and wildlife programs being more closely integrated with the SWP tha similar programs in most water projects, has been described by Tharratt and Beer (1974).)

Following this practice, and with growing attention to environmental impacts, DWR contracted with DFG in 1969 to study the impact o the SWP on wildlife resources in Southern California. This work, completed in 1972, conclud that over 16,000 acres of wildlife habitat wer lost because of the Project (Cribbs, 1972). The losses were on both National Forest System lands and on State lands that had been purchas for the SWP. Secondary (development) impacts were not included.

Following identification of the magnitude of the impact on wildlife, DFG studied alterna tives for mitigation of the wildlife damage (Gelfand, 1974). This study reviewed seven alternatives, and concluded with the recommendation of two of them: (1) mitigation of wildlife on Federal land be accomplished by acquisition and development of private inholdings within the boundaries of three National forests in which the impacts occurred, and (2) wildlife impacts on private lands acquired for the SWP be mitigated by acquisition and development of a wildlife area in the San Jacinto Valley.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, July 16-20, 1979.

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[3] Environmental Services Supervisor, California Department of Fish and Game, Sacramento, California.

LEGAL REQUIREMENTS

As mentioned above, both NEPA and CEQA were enacted during the time that the SWP wildlife mitigation study was underway. While neither of these acts is dominant in placing direct responsibility on the SWP for mitigation of wildlife impacts, both of them influenced actions by DWR and DFG and others because of disclosure requirements and policy expressions contained in the acts.

The Davis-Dolwig Act, California Water Code Sections 11900-11925, is the primary State law expressing policy concerning wildlife resources at water projects. It calls for "preservation" of wildlife, but agencies working with the Act have interpreted this to include concepts of mitigation or replacement as well. The Act declares wildlife preservation a necessity in the State's water programs, and assigns to DWR the role of making decisions in this area based on advice from DFG and others. Costs of wildlife preservation are identified as project costs to be included in the prices of water and power recovered from project beneficiaries in accordance with a cost allocation.

The Fish and Wildlife Coordination Act (FWCA) applies to wildlife decisions in the SWP in those areas where the project is constructed on Federal land or under Federal permit. The FWCA, although more broadly worded, and the Davis-Dolwig Act do not differ significantly as they have been applied in wildlife preservation or mitigation decisions in the SWP. Both Acts permit full programs to restore wildlife populations to preproject levels, and both require that these programs be at project expense.

Portions of the SWP in Southern California are licensed by the Federal Energy Regulatory Commission as Project 2426. In addition, DWR entered into four Memoranda of Understanding with the U.S. Forest Service (USFS) as a condition of constructing SWP facilities on National Forest System lands. These documents have all obligated DWR to take actions acreed upon to preserve or mitigate wildlife impacted by the SWP. The actions are consistent with those necessary to meet FWCA and Davis-Dolwig Act requirements.

MITIGATION ON NATIONAL FOREST SYSTEM LANDS

Initial negotiations with USFS were based on wildlife habitat losses amounting to over 7,000 acres. This included losses caused by inundation, construction of project facilities, recreation developments, and construction or realignment of access roads occurring at SWP locations in the Los Padres, Angeles, and San Bernardino National Forests, as reported by Gelfand, op. cit.

Detailed study upon entering negotiations resulted in correction of errors in basic data and land ownership maps, and the impact acreage was revised to 2,150 acres.

Throughout the negotiations the concept of acre-for-acre replacement of lost habitat prevailed. The negotiators often referred to the fact that different qualities of habitat justified other than acre-for-acre settlement, but the concept remained nevertheless.

In reaching agreement the impact acreage of 2,150 was further reduced to take into account the size and wildlife habitat quality of parcels in a land exchange between DWR and USFS. Hence the SWP's mitigation obligation was reduced to 1,500 acres.

Pursuant to the final agreement DWR will purchase in-holding parcels from a candidate list furnished by USFS. These will be turned over to USFS along with a specified amount of habitat development and operation funds. The total cost to the SWP is estimated to be $1,135,000.

This agreement has been made verbally and in a letter exchange between DWR and USFS. A formal agreement has been drafted and is nearly ready for signature as this paper is reaching completion.

DWR and USFS have been the primary participants in reaching agreements on the program for mitigation of SWP wildlife impacts on Federal land and in Southern California. Other participants have been DFG and the U.S. Fish and Wildlife Service.

MITIGATION ON PRIVATELY OWNED LANDS PURCHASED FOR THE STATE WATER PROJECT

Initial negotiations between DWR and DFG assumed that wildlife habitat on 9,300 acres of nonfederal land had been lost due to SWP construction. However, this figure was revised upward to approximately 12,000 acres as a result of a determination that initial basic data and land ownership maps contained errors.

The 12,000 acres took into account offsetting benefits that accrued to wildlife because of SWP construction. Further, it was agreed that wildlife was not completely removed from all of the impacted areas. DWR and DFG staffs decided after negotiations, that the impact on the 12,000 acres of habitat was equivalent to the complete loss of 9,000 acres of habitat. The 9,000-acre figure was thus the replacement goal or target as the two department staffs studied alternative mitigation projects.

Fifteen well-defined alternative mitigation projects were studied in an effort to reach a mutually acceptable plan to replace the SWP wildlife losses. Initially, DWR suggested use of surplus SWP lands at San Luis Reservoir, more than 200 miles to the north. This site was rejected because it was too far removed from the place of the impacts. DFG initially advocated acquisition and development in the San Jacinto Valley with emphasis on waterfowl management. The development was rejected because the project had not impacted waterfowl heavily.

As these studies of alternatives continued, two areas received primary attention as candidates for acquisition and development as mitigation areas. One was the San Jacinto Valley east of Lake Perris, a SWP feature. The other was the Peace Valley - Quail Lake area, which also contains major SWP features. In both locations (Figure 1) the mitigation alternatives considered would have used some SWP lands and some additionally purchased lands. All of the alternatives studied included not only land but development of habitat and management facilities and provision of operation and maintenance funds for a 50-year period. The costs of these were converted to present worth values for comparative purposes. No effort was made to relate benefits to costs or to study economic justification of the alternatives. Neither DWR or DFG believes it appropriate to subject fish and wildlife mitigation or preservation measures to tests of economic justification. Implicit in the Davis-Dolwig Act is the policy that preservation measures are a project obligation, and their costs are repaid by project beneficiaries.

Input by Others

Over the period of time that DWR and DFG were studying alternatives and attempting to reach agreement on a mitigation solution, other interests became increasingly involved. Environmental groups became concerned when they learned that the two departments were having difficulty in reaching agreement. They attempted to influence a decision along lines that they preferred.

SWP Water Service Contractors who have contracted to repay most of the costs of the SWP, including wildlife mitigation costs, became concerned when they learned that alternatives with present worth values as high as $25 million were being considered. They asked that lower cost alternatives be developed.

Others becoming involved and offering advice included landowners, county governments, and the U.S. Air Force, which was concerned that the proximity of the proposed San Jacinto Valley wildlife area would increase bird strike hazards to aircraft using March Air Force Base. The Office of the Legislative Analyst of the State Legislature investigated the program in connection with DWR's request for funds to implement a mitigation program.

DWR retained the services of a wildlife consultant to give advice on various aspects of the mitigation program early in the study. The Metropolitan Water District of Southern California (MWD), a leader of the water service contractors, retained the services of two consulting firms late in the study period to review additional alternatives.

The Solution

In November, 1978, almost ten years after initiating studies, DWR and DFG reached a tentative agreement on SWP wildlife mitigation (DWR, 1978). The agreement was for a $12.5 million cash settlement which DWR would furnish, and DFG would use to acquire and develop a wildlife area of about 9,000 acres in the San Jacinto Valley. The cash settlement included an amount of money estimated to be adequate for this acquisition, for development and for major equipment. It also included the estimated present worth value of the costs of operation and maintenance over the life of the project (50 years). In reaching this tentative agreeme both DWR and DFG compromised from previously held positions. Notably, the agreement represented commitment, at least partially, to acre-for-acre replacement of lost wildlife habitat.

When the tentative agreement was announced, the SWP's water service contractors complained that the costs were too high. The amount of the total costs allocated to them was estimated to be nearly $11 million. MWD asked that implementation of the tentative agreement be delayed and that they be permitted to undertake a private contractor study. The request was granted and MWD was given until April 1, 1979, to retai consultants and conduct its study.

The consultants reviewed the work done by the State agencies and produced a recommendatio of their own. (Jones & Stokes Associates, Inc. and Multiple Use Managers, Inc., 1979). They proposed that the mitigation be accomplished by

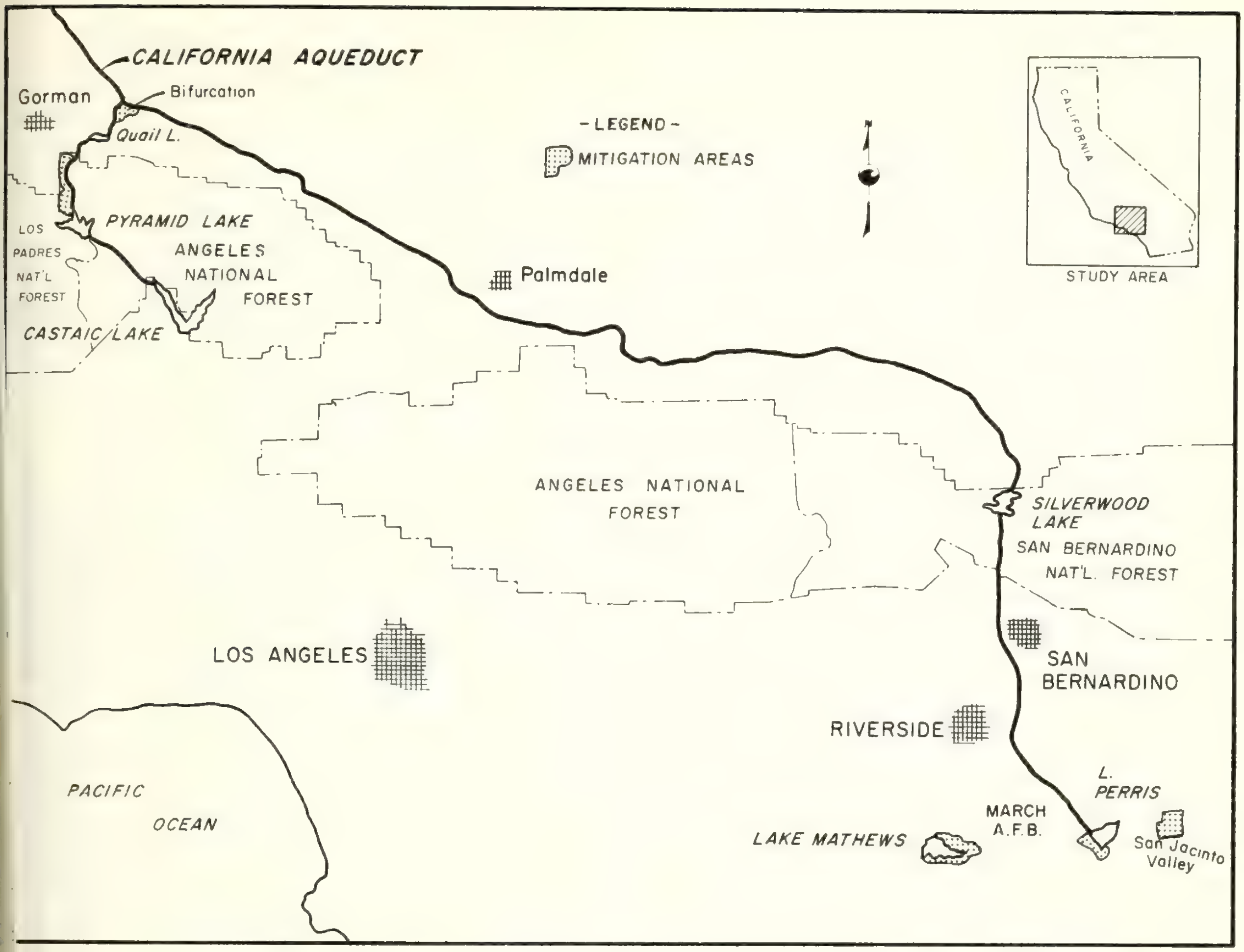

Figure I. WILDLIFE MITIGATION AREAS FOR THE STATE WATER PROJECT IN SOUTHERN CALIFORNIA

naging six areas in Southern California: ive of them already owned by DWR and a sixth Lake Mathews, owned by MWD. The acreage talled only 4,735 acres, a significant de- arture from the 9,000 that would be needed r acre-for-acre replacement. All six of the tes had been considered earlier by DWR and G, but not in the same sizes and not in the me combination. The estimated costs of the nsultants' plan is $6 million, all of which uld be used for development, operation and intenance, since all of the lands are already public ownership.

The MWD consultants' plan was not accepted the State agencies when it was presented cause of three major objections: (1) parcels attered too widely for efficient operation; (2) wildlife values did not adequately compensate losses; (3) high development costs. However, the agencies have reached verbal agreement on the matter, and the agreement incorporates many of the desirable elements contained in the consultants' plans. As this paper is reaching completion, DWR and DFG have announced agreement on a plan including development of wildlife habitat in the following five areas.

Below Perris Dam (SWP)	800 acres
San Jacinto Borrow Site (SWP)	650 acres
Bifurcation Area (SWP)	50 acres
Peace Valley and West Branch Area (SWP)	1,478 acres
Lake Mathews (MWD)	2,565 acres
TOTAL	5,543 acres

In addition, DWR will furnish water for a riparian vegetation corridor 2 miles in length in Peace Valley, $7 million in cash from SWP funds, and $1 million in other funding entitlements[4]. DFG will use these funds for development, operation and maintenance of wildlife habitat, and may purchase up to 4,400 acres of additional land in the San Jacinto Valley. MWD will maintain the wildlife habitat at Lake Mathews at no cost to DFG.

DWR and DFG have thus reached agreement on a program to mitigate damage to wildlife due to construction and operation of SWP in Southern California. The two agencies believe the program will do the mitigation job it is intended to do, and at a fair cost to those who must pay for the program. Some of the cooperators who have been involved are also satisfied with the results. Additional time must pass and the program must be implemented before it is known whether all who have contributed ideas or suggestions are satisfied.

DISCUSSION AND CONCLUSIONS

During the long period of study and negotiations, DWR and DFG have learned some lessons which will help them in future wildlife mitigation situations and might be helpful to others. Some of these are as follows: (1) Wildlife damage has gone unmitigated during the ten years of study and negotiations for this program. Five years were consumed in the studies, first to assess the damages and then to identify mitigation alternatives. The lengthy negotiations during the next five years were the result of complexity of the issues, and disagreement over magnitude of damages. Losses began in 1965 with the beginning of construction and were largely realized with completion in 1973 of the major project features. Mitigation will begin as soon as wildlife management is initiated under the agreement between DWR and DFG. This will probably start quickly in some areas, but a program this large will take several years to get into full operation. This experience serves to illustrate the extreme importance of early involvement of fish and wildlife in the planning process so that necessary studies can be completed and preservation measures functional at project completion; (2) Input to the studies and negotiations by other than the principle parties, while undoubtedly shaping the agreements in some ways, did not seem to speed up or slow down agreement significantly. It did, however, serve to identify issues that might otherwise have surfaced later and further delayed the preservation program. A major exception to this was input from the wildlife consultants hired by MWD. The consultants seemed to serve as a catalyst in the agreement, and following receipt of their report the principle parties reached the final agreement quite quickly. As stated earlier, the consultants did not introduce new locations or concepts that were not considered earlier by DWR and DFG. However, the settlement was not identical with the plan presented by the consultants; (3) Neither of the wildlife mitigation agreements - that for losses on Federal land or that for land purchased for the SWP - was completely based on acre-for-acre replacement of lost wildlife habitat. Both of them, however, were developed to some extent on an acre-for-acre concept. This is especially apparent with the Federal lands agreement.

We see nothing particularly wrong with acre for-acre replacement of habitat. However, our basic effort was to replace wildlife values, an the great diversity of wildlife habitat types in the impacted areas and potential mitigation areas make it unreasonable to expect that acreages in the two should be equal. In the absence of exhaustive biological data, however, shortcuts are sometimes needed, and acre-for-acre habitat replacement falls into the category of such a shortcut. Given the high cost of obtaining some biological data, or even its unavailability in some instances after project constru tion, judgments based on acre-for-acre replacement do not seem unreasonable; (4) During the period that the wildlife mitigation studies wer underway, decisions were made pertaining to wildlife enhancement in the SWP. Several SWP land areas that could have been used as wildlif mitigation areas were devoted to wildlife enhancement. These were usually developed with funds usable only for enhancement or recreation programs, and there was no longer any possibili of using the areas for mitigation. We believe that a better course to follow would have been to make no wildlife enhancement decisions until a mitigation plan was established. This would have left the greatest possible number of alternatives available for the mitigation program, which we believe to be of a higher priori than enhancement. In addition, the desire to make wildlife enhancement decisions would have put additional pressure on the mitigation program, which might have resulted in an earlier decision on mitigation; (5) The case presents an interesting contrast in intergovernmental cooperation on the fish and wildlife preservation issue when compared with similar issues in federally-supported water projects.

One might ask what are the ingredients for achieving successful resolution of fish and wildlife mitigation issues on State-constructed water projects.

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[4] State recreation bond fund and Land and Water Conservation Fund allocations to be used for public use facilities within the mitigation areas.

Basically, we see the principal components for success are the efficiencies inherent in the Davis-Dolwig Act which mandates fish and wildlife preservation and requires close cooperation between the construction agency and the fish and wildlife agency throughout the planning and construction process. The same cooperation between Federal construction agencies and fish and wildlife interests to consider fish and wildlife concurrently with engineering studies has been slow to evolve, thus limiting fish and wildlife mitigation options, and achievement of mitigation goals.

More important perhaps has been the positive attitude of decisionmakers in California's case in the formulation of water resources management and development plans which include fish and wildlife preservation and enhancement features. Undoubtedly, CEQA has had a positive influence on the overall process through public participation and support, but without the overall cooperation of the involved agencies, the achievements in environmental preservation would not have been as successful as they have been.

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The Corps' Role in Pacific Island Wetlands[1]

Robert J. Shallenberger[2]

Abstract. -- The Corps' Pacific Ocean Division has contracted ornithological and vegetation studies of wetlands in Hawaii, American Samoa, the Caroline Islands, and the Mariana Islands. The data generated in these studies are proving valuable in the effective implementation of regulatory policy and mitigation of impacts.

Extreme shortages of developable low elevation lands on Pacific islands, particularly on the densely populated islands, has led to the loss of many natural wetlands and the conversion to other uses of many more. The Corps' primary role in wetland protection stems from the 1972 amendments to the Federal Water Pollution Control Act (FWPCA), now known as the Clean Water Act of 1977. Section 404 of this Act established a permit program to regulate the discharge of dredged or fill materials into waters of the U.S. The Act recognized the diverse values of wetlands and provided a mechanism to evaluate the direct and cumulative impacts of proposed activities on wetland ecosystems. In the Corps' Pacific Ocean Division (POD), implementation of this Act has taken on long-range significance, as few of the wetland areas on any of the island groups in POD are adequately protected from adverse modification under other federal or local laws.

Wetlands on Pacific islands do not easily fit the classification systems developed for continental environments. Prior to Corps involvement, little effort had been directed towards documentation of wetland boundaries or site-specific wetland values. Exceptions include the few identified sites, particularly in Hawaii, of documented importance to endangered waterbirds. The Corps in the Pacific took on a lead role in wetland research in order to effectively implement its regulatory responsibility and to comply with other pertinent federal laws (NEPA, Fish and Wildlife Coordination Act, Endangered Species Act). Data gathered during Corps studies have proven instrumental in enhancement of wildlife habitat and mitigation of impacts associated with civil works projects and permit actions at several wetland sites. A field guide to wetland plants on Pacific islands is now in preparation by the Corps, using data gathered on these studies. Other agencies, including the Fish and Wildlife Service (FWS), have found the Corps reports to be valuable, comprehensive sources of pertinent data as well.

HAWAII

Both vegetation and ornithological studies were undertaken on five main islands (Kauai, Oahu, Molokai, Maui, and Hawaii) in the Hawaiian archipelago. A total of 78 sites was investigated. Natural wetlands include forested bogs, fresh and brackish marshes, estuarine mudflats, and riparian communities. Other wetlands created or highly altered by man include reservoirs, sewage ponds, aquaculture ponds, cane waste settling basins, agricultural fields (e.g., taro, watercress), and purposely-created waterbird habitats.

Many of the Hawaiian wetlands, including some highly modified sites, are of critical importance to the survival of four endangered waterbird species (Hawaiian Stilt, Himantopus mexicanus knudseni; Hawaiian Coot, Fulica americana alai; Hawaiian Gallinule, Gallinula chloropus sandvicensis; Hawaiian Duck, Anas wyvilliana). Special effort was directed towards a thorough documentation of habitat use by these species. Prior to the Corps study, waterbird habitat created to compensate for habitat losses in a major nearshore dredging project (reef runway) was incorporated into the National Wildlife Refuge System. The study data have been useful in development of enhancement habitat at a Corps flood control project (Kailua-Kaneohe Dam) and in planning for mitigation on several wetland permit actions.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Ft Collins, Colorado, July 16-20, 1979.

[2] Ecologist, US Army Corps of Engineers, Honolulu, Hawaii.

MARIANA ISLANDS

Vegetation and ornithological studies were also conducted in Guam and on islands within the Commonwealth of the Northern Marianas (Saipan, Tinian, and Pagan only). Unlike the high islands of the Hawaiian archipelago, most of the Marianas wetlands are mangrove swamps or freshwater marshes. Although most of the Marianas wetlands were virtually unstudied prior to Corps involvement, they have been subjected to accelerating adverse impacts due to expanding population on these small islands. These wetland sites perform a particularly critical function in the recharge of precious groundwater resources. They also provide habitat for rare wildlife, including two endangered birds (Marianas Mallard, *Anas oustaleti*; Nightingale Reed-warbler, *Acrocephalus luscinia*) and another waterbird currently under consideration for the Federal Endangered Species list (Marianas Gallinule, *Gallinula chloropus guami*). The Marianas mallard and the Marianas race of the reed-warbler are believed to be extirpated on Guam. They are now restricted to limited wetland habitat on islands in the northern Marianas, particularly at Lake Susupe on Saipan. The Corps has been investigating means to enhance habitat at this site and to mitigate adverse impacts that may occur as a result of contemplated flood control measures, while the FWS has initiated a captive propagation program for the Marianas mallard.

CAROLINE ISLANDS

Corps jurisdiction in the Pacific under Section 404 also includes the Trust Territory of the Pacific Islands. The Corps wetland vegetation studies included five districts (Kosrae, Ponape, Palau, Yap, and Truk) within the Caroline islands of Micronesia. Coverage of this wetland study was limited to the high islands, while atolls were excluded. The "natural" wetlands include mangrove forest, coastal saline marsh, lowland freshwater marsh/open canopy swamp, upland high canopy swamp forest and riparian communities. Other wetlands covered in the survey reflect a history of human alteration, particularly that related to agriculture. Large, undisturbed tracts of mangrove forest and swamp forests on Kosrae, Ponape, and Palau were recommended for preservation and several wetland plant species were suggested for future consideration as "endangered."

The Corps has not conducted ornithological surveys of Caroline island wetlands, although limited data from earlier studies are available. None of the six Caroline island bird species presently listed as endangered by federal law are wetland species, although several additional birds, including some wetland species, are listed by Trust Territory law only.

AMERICAN SAMOA

Botanical studies of wetlands in American Samoa were confined to 17 mangrove forests and coastal marshes, totalling only 223 acres. The limited accessible flat land near the coasts has put extreme pressures on wetlands for agricultural use and village expansion. These natural wetlands buffer storm waves and serve as nursery and breeding grounds for many fish species. In addition, several rare wetland plant species have been suggested for federal protection.

A separate ornithological survey of American Samoa wetlands was not contracted by the Corps because of the availability of data from extensive field research recently contracted by the FWS and data gathered during site visits by Corps biologists. No birds in American Samoa are currently protected by the Federal Endangered Species Act, although several species have been recommended for consideration. No wetland birds are confined in distribution to American Samoa.

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The Preservation and Restoration of San Francisco Bay Fish and Wildlife Habitats[1]

JoAnne Mensch Sorenson,[2] Charles R. Hazel,[2]
H. Thomas Harvey,[3] and Michael V. Dyett[4]

Abstract: Historic, existing and future fish and wildlife habitats in and around San Francisco, San Pablo and Suisun Bays were mapped. Comparisons were made of several possible future scenarios. Options and recommendations were presented for future federal, state, regional and local governmental actions to preserve and restore fish and wildlife habitats.

San Francisco, San Pablo and Suisun Bays and the Sacramento-San Joaquin River Delta form a complex that is a center of commerce for California and the western United States. Almost 5 million people live and work in the Bay Area and are tied through the Bay-Delta complex to another 3 million people in the Central Valley of California.

In addition to being an urban and commercial center, the Bay Area also supports a remnant of a once vast estuarine system composed of open water, salt and brackish marshes and adjacent lowlands. During the period when the Bay Area population grew from less than 25,000 (1849) to over 5 million (1979), 300 square miles of intertidal marshland were reduced to 50 square miles. The fish and wildlife resources supported by these wetlands were displaced by agricultural, residential, commercial and industrial development, ports, salt evaporation ponds and other human-related land uses. Over-exploitation by market hunting and fishing reduced once abundant stocks to low numbers or, in some cases, to nothing. Air and water pollution degraded remaining habitats, further reducing fish and wildlife resources.

The efforts of local citizenry and some lawmakers culminated in the formation of the San Francisco Bay Conservation and Development Commission (BCDC) which in the last 10 years has slowed the losses of fish and wildlife habitat. The study being reported in this paper was undertaken in 1978 (1) to identify, map and describe existing fish and wildlife resources and habitats in the Bay Area; (2) to describe human-derived conditions and activities that are continuing to diminish fish and wildlife habitats; and (3) to identify courses of action available to agencies at all levels of government to protect and restore wetland habitats in the Bay Area. The report, San Francisco Bay Fish and Wildlife Habitat Protection and Restoration, prepared for the California Department of Fish and Game (DFG) and the U. S. Fish and Wildlife Service (FWS) will be available August 1979.

The wetland, intertidal and subtida habitats of the Bay Area were described and mapped in some detail (1:24,000). Habitat classification was based on the FWS system developed by Cowardin, et al., (Classification of the Wetlands and Deep-Water Habitats of the United States, 1977) modified to include land use categories and habitats specific to the Bay Area. Graphic and numerical comparisons were made of historic (pre-1850) and existing marsh habitats to evaluate the effects of past human activities on present fish and wildlife resources. Compared with 125 years ago, only one-sixth as much intertidal wetlan habitat is present today. It appears that three general activities have been the paramount destructive forces upon fish and wildlife habitats:

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[1] Presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Jones and Stokes Associates, Inc., Sacramento, California

[3] Harvey and Stanley Associates, Alviso, California.

[4] John Blayney Associates, San Francisco, California

- The covering of tidelands and shallow water areas with fill material or dredge spoil.
- The diking of tidelands and the prevention of tidal submergence of such lands.
- The discharge of pollutants to the Bay from municipal, industrial and marine vessel sources.

Two future scenarios for fish and wildlife habitat in the Bay Area were described and mapped. The development scenario was based on the premise that conversion of fish and wildlife habitats to urban and industrial uses would continue as projected by local government in their land use plans and zoning ordinances. The potential loss of existing or former wetland habitat through implementation of local plans was estimated at 23 square miles.

A second scenario displayed the maximum fish and wildlife habitat achievable through maintenance of existing wetland habitat and the restoration of lands prepared for some type of development (diked and/or filled), but as yet still free of structures. Over 100 square miles of former wetlands were available for restoration to wetland habitats. Categories of restoration opportunities and methodologies were described and discussed in the report.

The conversion of existing and former wetlands to some more intensive land use occurs within the framework of existing laws, regulations, policies and practices of the various governmental agencies exercising jurisdiction in the Bay Area. During recent years, some governmental agencies with responsibilities for land conversion have taken great strides toward natural resource conservation in the Bay Area. Certainly the McAteer-Petris Act (establishing BCDC) and the California Environmental Quality Act have greatly contributed to the maintenance of wetland habitat on the state level, while federal laws and procedures have supported resource conservation.

The analysis of existing governmental procedures for land use conversion revealed that the DFG and the FWS are generally successful, on the one hand, in their protection of fish and wildlife habitats through their participation in the BCDC, Corps and other state and federal agency permit application reviews. On the other hand, the DFG and FWS have not been particularly successful in protecting fish and wildlife habitats under local government permit application reviews. This lack of success is directly related to DFG and FWS late or nonexistent entry into the planning process at the local levels. DFG or FWS presently provide fish and wildlife resource data when they comment on Environmental Impact Reports (EIRs); but the EIR review comes late in the land use planning process, and DFG or FWS comments may be completely disregarded.

The report offered a number of possible courses of action or options which DFG and the FWS could implement to provide better protection, maintenance and restoration for Bay fish and wildlife habitats. The suggested actions range from encouraging other agencies to change their procedures, to seeking changes in federal or state law. Emphasis was given to those options which could improve the incorporation of fish and wildlife habitat protection and restoration in local general planning and zoning processes.

The DFG and FWS identified several of the options as specific agency recommendations, including: (1) expanding the jurisdictional boundaries of the BCDC to include more existing and historic wetlands, (2) providing local agencies with fish and wildlife habitat information and assistance in evaluating permit requests, (3) reviewing local government plans for all land use changes within the study area and making recommendations for habitat protection, and (4) developing a land bank. DFG and FWS guidelines and policies in relation to San Francisco Bay were clearly defined.

Mitigating Wetland Deterioration in Southeast Louisiana[1]

Gordon Meeks, Jr.[2] and Sherwood M. Gagliano[3]

Southeast Louisiana is predominantly wetlands, marshes, tidal estuaries and river ridges entirely constructed by centuries old deltaic processes of the Mississippi River. Early settlements were originally established on ridges, natural levees, formed by seasonal flooding of the Mississippi River, its distributaries and bayous and the deposition of sediment load. As the population grew and immigration continued, urban and agricultural development spread into the lower elevations and wetland habitats. Elevation gradients are very slight, and in much of this terrain, the surface is below sea level.

With colonization and the institution of formal governing authorities by the Spanish, French, and subsequent American governments, complete leveeing of the Mississippi was accomplished in the eighteenth and nineteenth centuries. Leveeing of the river has permanently eliminated the natural deltaic processes which throughout the ages have primarily determined the geologic conditions of the area. Cut off from the continuel source of sediment, marshlands and estuarine prairies are naturally subsiding and eroding. Hurricanes and other tidal actions aggravate the rate of wetland deterioration in this coastal zone.

Other man-induced alterrations of the surface hydrology have exacerbated the problem. Exploration for oil and gas has necessitated the dredging of canals and access slips for drilling and pipeline construction. Navigation channels for interstate and international shipping have also been dredged. Although not as numerous, individual shipping canals are larger and lengthier. The environmental result of chanelization has been an exceleration of erosion and rapid transition of vegetation zones which has led to a radical decline in productivity of wildlife and estuarine dependent species in certain geographic zones.

The primary hydrologic impact of canal construction has been saltwater intrusion. Oil and gas and navigation channels provide faster tidal flow, upstream and downstream, than does natural channel or sheet flow in prairie marsh. The largest and most significant canal contributing to this problem is the Mississippi River - Gulf Outlet (MRGO), dredged to a thirty-six foot depth and five hundred foot width in the early 1960's. This canal bisects the Parish of St. Bernard, La., due east of New Orleans.

St. Bernard Parish encompasses a deltaic lobe created by the Mississippi as it flowed in four ancient and now abandoned river channels; Bayous La Loutre, Terre Aux Boeufs, Des Familles and Sauvages. Loss of sediment and nutrient replenishment by the natural river processes has been profoundly compounded by saltwater intrusion via the MRGO. Directly attributable to this canal are loss of more than 6400 acres of bald cypress and tens of thousands of acres of fresh and intermediate marshland vegetation. This vegetation contributed to the food chain for muskrat, nutria and estuarine dependent seafood. Louisiana produces forty percent of the nation's fur and is the number one producing state for seafood and industrial fish. St. Bernard ranked high among the coastal parishes of Louisiana. The environmental degradation of St. Bernard's wetlands has therefor had widespread economic, social and, recently, political repercussions.

Since 1968, when planning for an additional navigation channel began in earnest, St. Bernard has been pursuing an aggressive policy towards wetland research and conservation. Fishermen and trappers in the Parish have for decades lobbied for construction of projects to mitigate the effects of saltwater intrusion, erosion, and subsidence. The primary management concept for addressing these demands has been and is diversion of freshwater, in controled amounts, from the Mississippi River into marshes and wetlands in states of deterioration.

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[1] Poster presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Senior Planner, St. Bernard Parish, Louisiana.

[3] President, Coastal Environments, Inc., Baton Rouge, Louisiana.

In December of 1978, construction on a freshwater diversion siphon began at lake Borgne Canal in Violet, Louisiana. This diversion structure is comprised of two 50 inch pipes with attached suction valves extending from the river over the river levee, under railroad tracks and a state highway, to the Violet Canal which feeds into a 20,000 acre plus brackish marsh. This wetland area has experienced the most dramatic transition as a result of saltwater intrusion.

This is not the first such diversion of river water. There are four others in Plaquemines Parish which have proven the success of freshwater diversion. The St. Bernard siphon is the first, however, to be constructed in combination with application of scientific management principles. One Hundred percent funding for the siphon is being provided through the Coastal Energy Impact Program of the Office of Coastal Zone Management, NOAA. In conjunction with this grant, the Parish is developing an operational management program which will monitor water quality and develop a construction program to optimize distribution of freshwater to areas in the marsh which most need dilution of salt concentrations.

Concurrent with construction of the siphon, an additional grant has been approved to fund equipment for a permanent, comprehensive, wetland management program. This program will encompass construction of water control structures to minimize erosion and maximize hydrologic conditions favorable to fish and wildlife productivity. The prime objective of these programs is to simulate historical deltaic ecological systems.

The Parish has developed a comprehensive Coastal Zone Management Program which includes structural and non-structural measures. St. Bernard is assuming all maintenance and operational expenses in addition to continuing planning elements subsidized by Section 5 CZM grants. An old three story school building is currently being renovated as offices, meeting rooms, educational center and storage space for the implementation and enforcement of major elements of the Coastal Zone Program. The State Legislature is supporting these programs on a local and statewide basis, and at this point, St. Bernard has a model environmental policy for local governmental institutions. This program is under the tutelage of the National Coastal Zone Management Program but conceptually has positive implications for productive management programs by local governments elsewhere.

Mitigation of Lost Fish Production in the Senegal River After Dam Construction[1]

Donald Dorfman[2]

The proposed construction of an anti-salt dam in the Senegal River and a second dam on a feeder river will result in an estimated annual loss for human consumption in Senegal, Mali and Mauritania of 20,000 tons of fish. Mitigating measures include aquaculture, development of offshore fisheries, and creation of a small estuary.

A number of dam projects are planned for West Africa. Two are proposed for construction on the Senegal River. The river and its tributaries flow through Senegal, Mali, Mauritania, and Guinea. One dam, to be situated in the lower estuary of the river, is designed to eliminate salt water intrusion beyond 45 kilometers from the river mouth. The second dam, to be built on the Bafing River, a major tributary of the Senegal, is designed to limit annual inundation of the floodplains along the middle valley of the Senegal River.

Each dam will create impoundments which will, locally, increase water surface area and, concomitantly, increase fish production within these localized areas. However, considerable losses of fish production will occur in major areas of the river. These losses will far exceed impoundment gains. The anti-salt dam will prevent the movement of anadromous and catadromous fishes between the low and high delta, eliminating a productive estuarine fisheries and an important nursery area for both fresh and salt water fishes. Estuarine characteristics will occur for less than one month in the river as opposed to nine months prior to dam construction. Because of high evaporation rates salinities on the downstream side of the dam may exceed 40 ppt, eliminating fish habitat in this part of the river. The Bafing River dam will, for the most part, confine the river flow to its minor bed, resulting in the loss of floodplain fisheries. The floodplains are enriched with organic materials during the dry season with cattle and sheep dropping and herbaceous plant material. The areas normally inundated in the middle valley along the Senegal River are heavily exploited by many fish species which feed and spawn in these inundated floodplains. Subsequently, the newly spawned fishes utilize these same areas as a nursery and they can avoid capture by predaceous fishes because of the shallowness of the waters. Additionally, organic matter normally carried by the Senegal River to the ocean during the annual flood may be deposited in the impoundments created by the dams. This could result in a drop in the offshore fish catch. However, coastal Senegal and Mauritania are areas of upwelling, and the nutrient supply added by the river may not contribute measurably to the total nutrients available in that part of the ocean.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Associate Professor, Monmouth College, West Long Branch, New Jersey 07724.

Alternative dam sites are not feasible since these would interfere with the planned functions of the dams (these functions include irrigation, navigation, and power generation).

To mitigate the estimated loss of 20,000 metric tons of fish annually for human consumption, Senegal and Mauritania could exploit their coastal fisheries, which presently are being fished by foreign fleets. This requires capital expenditures by both countries for ocean going vessels, a port and processing facilities (in Mauritania), and an upgraded road system to adequately distribute fish for sale inland.

A second means of mitigation is the development of intensive aquaculture in the basin, preferably utilizing native fish species. Pilot aquaculture projects, sponsored by local government or international aid (e.g. U.S. Peace Corps), could be established in conjunction with newly developed irrigation agriculture schemes. However, because of the harsh environmental conditions in the basin (i.e. disease, intense heat, and high rates of evaporation), little technology, and poor roads and marketing conditions, this measure may be impractical.

Another means of mitigation, specifically for maintaining estuarine conditions, is the construction of a canal from the reservoir created behind the anti-salt dam to a second, shorter river system, the Tialkot-Bell, a tributary of the Senegal River, and which originates in the lower estuary of the Senegal (Fig. 1). This new river regime, possibly requiring energy inputs to maintain a flow of fresh water, might maintain the productivity of the estuary by providing conditions for reduced salinities for estuarine fishes, crabs and shrimps. A study to determine the feasibility of such a canal should be undertaken prior to dam construction and if feasible, its construction and completion would coincide with that of the dam, thus maintaining the viability of the estuary.

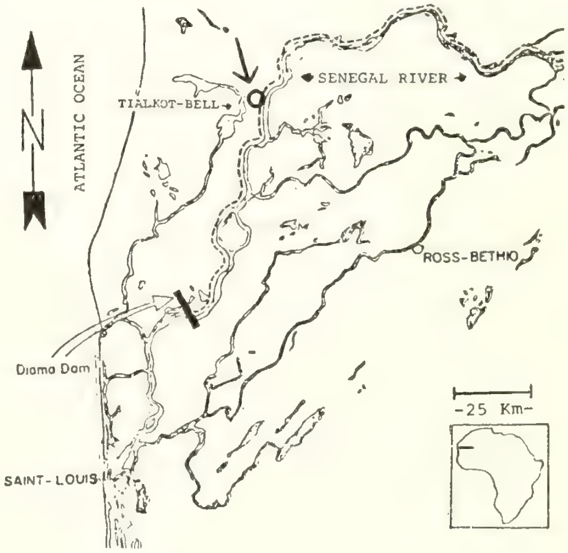

Figure 1. Map of the lower Senegal River. Circled area indicates the suggested site of a canal between the river and the Tialkot-Bell to form a new estuary. Line on insert map shows location of the Senegal River.

Hawaiian Streams: Diversion Versus Natural Quality[1]

J. A. Maciolek[2]

Abstract.--West Maui provides an example of excessive stream diversion in Hawaii. Most of its streams are dewatered resulting in the loss of 80 km of habitat and severe depletion of fauna. Protection and restoration of flow were attempted; faunal recolonization via improved channels appears promising.

INTRODUCTION

Freshwater frequently is the primary factor limiting socio-economic growth on oceanic islands, leading to heavy reliance on stream sources in some localities. More than half of Hawaii's 366 streams are diverted to some extent (Timbol and Maciolek 1978), many being dewatered at normal flow. Diversion is particularly detrimental to the prominent native stream fauna which requires access to the ocean as well as migratory pathways to habitat above points of water removal.

Although diversion is but one of several factors combining to degrade streams statewide, it is the principal one in many areas. This report focuses attention on one such area, West Maui, where growing water demands conflict with attempts to alleviate stream degradation.

SURFACE WATER NEEDS AND SOURCES

Early Hawaiian society evolved around diversion of most streams of the archipelago for irrigating taro, the principal ancient crop. Impact on stream ecology probably was minor because such diversions were partial and water was not exported from drainages. Modern agriculture has had a vastly greater impact because the current principal crop, sugar cane, is highly dependent upon water. Stearns and Macdonald (1942) estimated that an average of 3,000 lbs of water was needed to produce a single pound of raw sugar (3 m^3/kg sugar), exclusive of rainfall. During the past century sugar became Hawaii's primary agriculture by utilizing water from all feasible sources--which included the total diversion of many streams and export of the water to cane lands.

Surface water supplying native domestic needs was replaced by groundwater in most localities as modern society evolved. Water demanded by recent population and commercial growth (including resort development) has exceeded groundwater supply in areas such as West Maui. Consequently, there has been an increasing use of stream water for domestic needs. A recent engineering survey (Wilson, et al. 1977) estimated that the 1975 domestic water consumption in Lahaina District (West Maui) of 4.3 mgd (11 m^3/min) would nearly double in 1980, and double again (to 40 m^3/min) by the year 2000. Currently, water diverted from five streams is helping to meet that demand. The survey further indicated that cane irrigation in the Lahaina District has a stable and continuing water demand of 80 to 90 mgd (210-240 m^3/min), about half of which is diverted from streams.

West Maui, although a relatively small landmass, has rainfall that exceeds 1,000 cm/yr on the central highland. Precipitation feeds 17 perennial streams, all of which are diverted to some extent. At least 14 of the larger streams apparently discharged to the ocean year-round before diversions were imposed. Some features of those 14 streams are given in Table 1 and Figure 1. Basin areas are those portions of the total drainages effective in contributing to low flow (roughly, basin areas lying above the 150 cm/yr isohyetal line). Discharges are arithmetic mean flows from records of gaging stations usually located near diversion sites (data from Yamanaga and Huxel 1969, 1970 and earlier sources). Such means are biased upwards by freshet discharges; flow-duration curves for a few streams suggest that "normal" discharges are about one-half those of the arithmetic means. Percentages of flows diverted are personal estimates made by observing lower reaches of the streams during periods of normal flow. Several of the streams receive groundwater recharge below the initial diversion point; where recharge is significant, streams are rediverted (up to three times). Recharge maintains minor flow in the lowermost reaches of two streams (Honokohau, Waihee).

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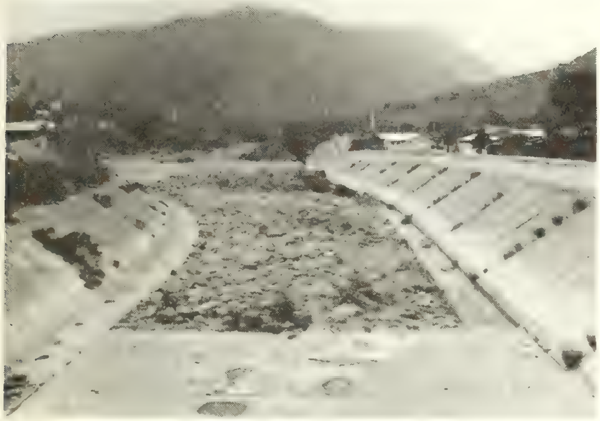
[1] Presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Hawaii Cooperative Fishery Research Unit (U.S. Fish and Wildlife Service), University of Hawaii, Honolulu, Hawaii 96822.

Table 1.--Drainage areas, mean discharges, and effect of water loss on perennial West Maui stream ecosystems.

Stream	Basin area km^2	Discharge mean, m^3/min	Discharge % diverted	Habitat lost, km stream	Biological quality
Waihee	15.8	158	100	4.8	C
Iao	18.1	132	100	7.5	D
Honokohau	21.5	68	100	7.7	C
Kahoma	11.9	32	100	11.1	D
Waiehu	7.0	30	100	5.0	C
Kaulaula	6.2	29	100	5.9	D
Kahakuloa	9.8	29	10	0	A
Olowalo	10.6	26	100	3.6	B
Waikapu	7.0	24	100	12.5	D
Ukumehame	10.9	21	100	1.7	B
Honolua	6.0	15	100	5.0	D
Honokowai	8.5	11	100	8.6	D
Makamakaole	2.8	6	50	0	A
Launiupoko	4.4	4	100	4.5	D



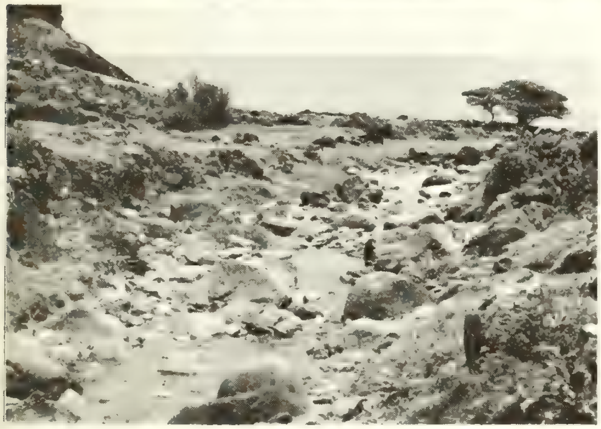


Figure 1.--Representative West Maui Streams. Top: Lower Iao, second largest of 15 streams totally diverted at normal flow. Bottom: Makamakaole, a high quality stream and one of two discharging perennially to the ocean.

EFFECTS ON STREAM ECOLOGY

Partial diversion may result in some deterioration of stream quality below the point of water removal, such as increases in temperature and sedimentation as well as decreases in habitat space and shelter. Total diversion obviously annihilates a portion of the stream ecosystem. As shown in Table 1, only two of West Maui's perennial streams, Kahakuloa and Makamakaole, remain watered throughout and discharge continuously to the ocean. Together, they constitute only 9% of West Maui's effective drainage area and 6% of its total mean runoff. The amount of habitat eliminated in the remaining 12 streams varies with elevation and distance inland to the uppermost diversions. These factors range from 70 m elevation and 1.7 km inland (Ukumehame) to nearly 600 m elevation (Kahoma) and 12.5 km from the ocean (Waikapu). Based on distance inland, nearly 80 km of stream have been eliminated ecologically among the 12 streams completely diverted, a loss averaging 6.6 km per stream.

The unique nature of native Hawaiian stream fauna was described briefly by Maciolek (1975). Present focus is on all of the large native aquatic animals, exclusive of insects, that inhabit lower and middle reaches of streams. The group consists of only 10 species, eight of which are diadromous and two are euryhaline marine fishes (mullet, kuhliid bass) that frequent lower reaches as juveniles. The diadromous fauna, stream residents whose larvae must develop in the ocean, comprise five gobioid fishes, two crustaceans (shrimp and prawn), and a large neritid snail. All of the 10 species require marine access; eight of them are endemic to Hawaii, and at least five have recreational and commercial value. All species are depleted statewide, and one (goby, Lentipes concolor) has been nominated as rare and endangered. Five of the species are confined to lower stream reaches, two species inhabit both lower and middle reaches, and three occur only above the lower reaches. One species (shrimp, Atya bisulcata) resides at altitudes to 1,000 m. Probably no stream contains large populations of all species; a pristine stream could have seven or eight of them. A few of the diadromous species can migrate upstream rapidly (as postlarvae) and colonize some streams above a diversion point during wet seasons if high runoff sustains overflow for a few weeks and if perennial water is not too distant.

Ecological quality of each stream (Table 1) was assessed according to the amount of habitat lost, and by the numbers of native macrofaunal species in perennial waters observed or collected during field surveys. The letter rating used is based on a pristine stream (no habitat loss and populations of at least seven species present) being Class AA. The only streams approaching such a rating were Class A Kahakuloa and Makamakaole, the two with perennial ocean discharge. Both harbored six species of native macrofauna including the rare goby, Lentipes concolor. Populations of three native species were found in Class B Olowalu and Ukumehame, both diverted near the ocean relative to other streams. The remaining 10 streams were decidedly more degraded ecologically; it should be noted that none of them has habitable water for the 5 species characteristic of lower stream reaches.

ENVIRONMENTAL PROTECTION AND RESTORATION

Faced with a growing water problem, Maui County has imposed a series of temporary building moratoria, two of which are currently in effect. To meet demands, other water sources have been evaluated including further diversion of streams (Wilson et al. 1977). Growing environmental opposition to such tranditional stream water expolitation has taken two directions, protection of existing natural quality and environmental restoration.

Currently, one pristine stream in the state has strong protection under the Estuarine Sanctuary Act. Another is less well protected by the National Park Service (Haleakala NP). Beginning 7 years ago, the Hawaii Natural Area Reserves System Commission proposed (without definitive results) that several high quality streams in the State be protected as parts of natural area reserves (Maciolek, 1975). Included were the two significant streams remaining on West Maui. Greatest protection of stream ecosystems has come from the Hawaii Department of Health through water quality standards that also protect the biota indirectly. In a 1978 provisional revision of water quality standards, the Health Department proposed to regulate stream flow to preclude any further diversion of high quality streams; the issue proved controversial and was deleted from the final draft.

Restoration of stream ecosystems is a new concept in Hawaii. The deleted portion of the aforementioned water quality standards revision would have included minimum flow requirements for some totally diverted streams (those with suitable habitat above the point of water removal). Minimum flow regulation would allow release of sufficient water for the upstream migration of diadromous post-larvae and downstream passage of their hatchlings. An innovative approach to enhance such migrations is being attempted on West Maui by the U.S. Army Corps of Engineers as a public works project (Figure 2.) It involves rechannelization of the degraded lower section of Iao Stream to simulate natural stream bed conditions. The new channel is to have boulder-studded grout with a step-down (low flow) subchannel. The intent is to provide cooler water and shelter for upstream migrants during periods of diversion overflow (when discharge exceeds ditch capacity). If successful, the new channel will allow recruitment of diadromous fauna to extensive prime habitat in the midreaches of Iao. Success of the endeavor probably would be assured under the proposed minimum flow regulation.

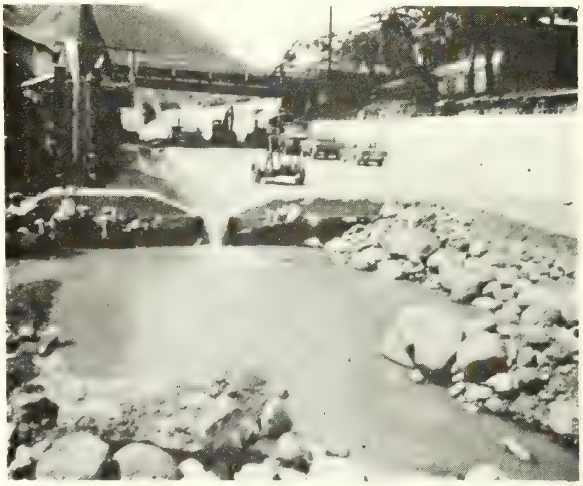


Figure 2.--Rechannelization of Iao Stream (cf. Fig. 1) to enhance faunal migration during diversion overflow. Step-down subchannel to concentrate low runroff; entire channel base to be overlain with rock-studded grout to provide shelter and aeration.

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Wildlife Mitigation on the Sacramento River, California: A Case Study[1]

Fred Kindel[2]

Background: (Sacramento River; riparian wildlife habitat; human population; flood protection improvements; environmental impacts).

Sacramento River Flood Control Project: (construction initiated 1918; major project items completed; 977 miles of levees transferred to State flood control agency for operation and maintenance).

Sacramento River Bank Protection Project: (erosion of levees overtaxed State's capabilities; joint Federal/State bank protection project authorized in 1960 at two-thirds Federal cost and one-third cost and O&M by State; recreation developments included; construction of first phase -- 430,000 lineal feet. Completed in 1974; second phase of 405,000 lineal feet authorized in 1974, including mitigation for second phase work at cost allowance of 10 percent of bank protection work; construction of second phase initiated 1975).

NEPA Environmental Analysis (EIS filed with CEQ in 1973; State Department of Fish and Game and Fish and Wildlife Service requested further fish and wildlife studies; narrow riverside riparian wildlife habitat judged very important; Corps requested Fish and Wildlife Service to study wildlife losses and mitigation need of phase one work; Fish and Wildlife Service report in 1976).

Fish and Wilflife Service Analysis: (supporting data explained; importance of narrow riverside riparian wildlife habitat confirmed; some 668 acres recommended for mitigation).

Corps Preliminary Analysis: (lost wildlife habitat should be in two categories: (a) loss from maintenance of completed levee project, and (b) loss from new bank protection; tentative plan includes mitigation of 260 acres for loss from new construction at two-thirds Federal and one-third State cost; however, mitigation for loss from maintenance of 408 acres not a Federal responsibility since maintenance is a State responsibility; possibility for enhancement plan identified to provide 408 acres at three-fourths Federal and one-fourth State cost).

Future Action: (completed Corps report will be processed for Congressional authorization).

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[1] Poster presentation at the Wildlife Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Chief, Environmental Planning Section, Sacramento District, Corps of Engineers, Sacramento, California 95814

Wetland Preservation in the Atchafalaya Basin[1]

James R. Butch, Victor W. Lambou and Stephen C. Hern[2]

A flood control project threatens to reduce wetland habitat within the vast (1800 sq. mi.) Atchafalaya Basin Floodway in Louisiana. Conceptual management units (distinct hydrologic floodway units) have been designed to accommodate flood control and maintain high levels of environmental quality. Implementation of the management unit concept will help to prevent the loss of many thousands of acres of wetlands.

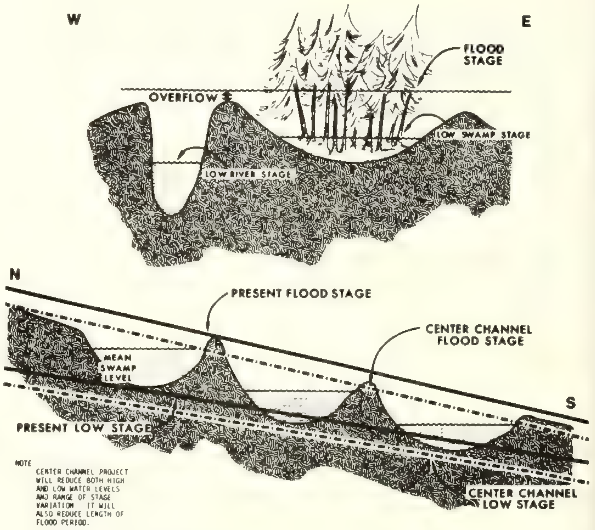
INTRODUCTION

The Atchafalaya Basin is a large shallow depression located within the deltaic plain of the Mississippi River in southern Louisiana. The Basin is an area of national importance which provides extensive natural resources as well as wetland habitat for rare and endangered species.

The Army Corps of Engineers has proposed a project to channelize the Atchafalaya River for the primary purpose of controlling floodwater flows within the Basin area. One channelization alternative under consideration advocates the dredging of a 100,000 square foot cross section channel along nearly 30 miles of the Atchafalaya River.

THE PROBLEM

The most severe environmental impact that would result from the proposed Atchafalaya center channel alternative would be the lowering of the average annual stage of the Atchafalaya River up to 4 feet. (Gagliano and van Beek, 1975; van Beek et al., 1977). The immediate and direct impact of this reduction in average annual river stage would be to decrease the extent and duration of overbank flooding of up to 590,000 acres of wetlands (fig. 1). This would result in the loss of: (1) productive breeding, nursery and feeding grounds for important sport and commercial fish, (2) prime habitat for waterfowl and other wildlife; (3) nutrients and fixed energy to the lower estuary and gulf; (4) natural water purifier areas (5) high recreational use areas.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NOTE
CENTER CHANNEL PROJECT WILL REDUCE BOTH HIGH AND LOW WATER LEVELS AND RANGE OF STAGE VARIATION IT WILL ALSO REDUCE LENGTH OF FLOOD PERIOD.
CENTER CHANNEL LOW STAGE

Figure 1. Schematic cross-section and longitudinal section showing the interrelationship of basin channels, floodbasins, depressions, and their associated natural levee ridges. Center channel project will reduce both high and low water levels and range of stage variation. It will also reduce length of flood period.

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[1] Paper prepared for poster session presented at the Mitigation Sysposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Respectively, Aquatic Biologist, Environmental Protection Agency (EPA), Washington, D.C.; Chief, Water and Land Quality Branch, EPA, Las Vegas, Nevada; Microbiologist, EPA, Las Vegas, Nevada.

THE SOLUTION

The establishment of management units (distinct hydrological units of the floodway) has been proposed by EPA in order to accommodate flood control and maintain an acceptable level of environmental quality.

The proposed management units (fig. 2) consist of areas in the Basin segmented by natural levees or manmade dredged spoil embankments.

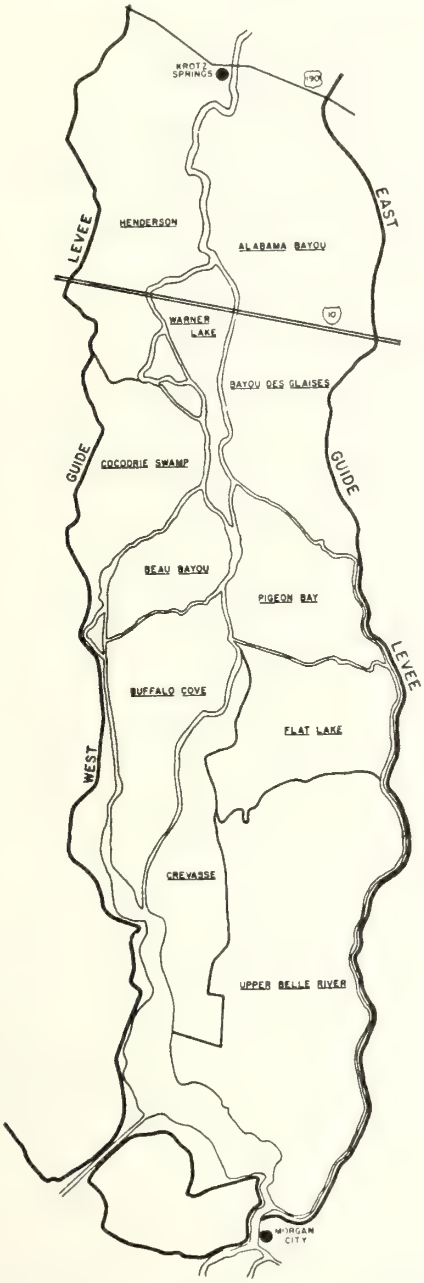

Figure 2. Location of proposed management units

Structural features would be built to control water levels within each of the management units. In order to protect the important ecosystem values of the wetlands, management units would be operated so that: (1) water level fluctuations would mimic, as closely as possible, natural water overflow patterns; (2) there would be proper headwater flow and circulation throughout each unit; (3) nutrients and fixed energy would be discharged through the system to the lower estuary and gulf area; and (4) sediment deposition would be reduced within the wetlands. Figure 3 shows the operational concept of a typical management unit.

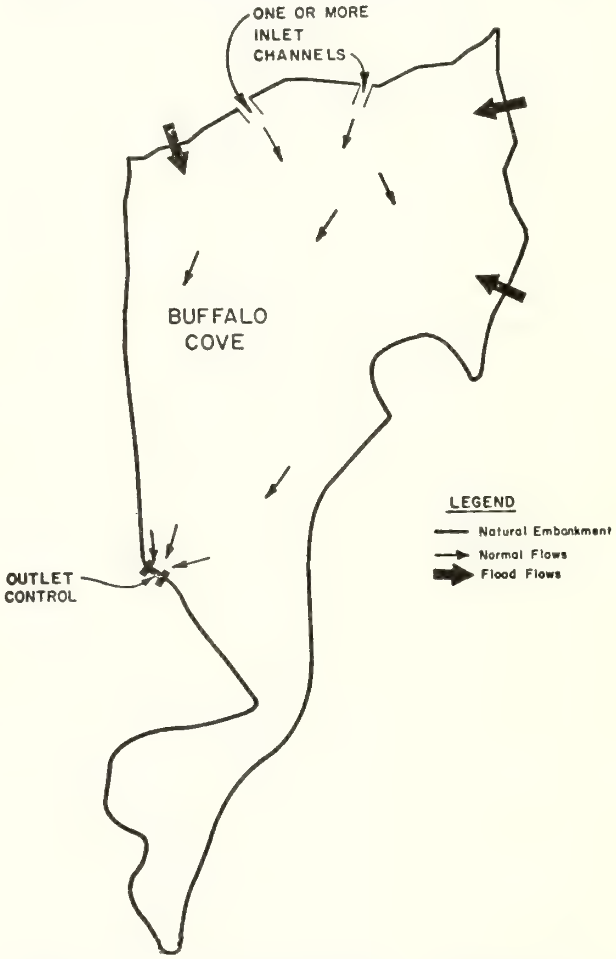

Figure 3. Conceptual design of a management unit. Gaps in the natural embankment would be raised as necessary to confine average annual flows.

THE BENEFITS

Implementation of the management unit alternative would ensure that the natural annual watering and dewatering cycle of the Basin's backwater wetlands would be preserved.

Through the proper design and placement of control features, water circulation and water quality would be maintained or improved within each unit. The management units would perpetuate the high recreational, commercial, and environmental values of the Basin.

CONCLUSION

The natural environment of the Basin dictates that its use is ultimately determined by the hydrologic regime, with wetlands an integral part. Optimum use of the area as a floodway as well as a functional wetland ecosystem, will require an effective water management plan based on an understanding of the multi-purpose values the Basin provides. The management unit concept is a viable alternative of multi-purpose planning that recognizes both environmental opportunities and the necessity for flood control.

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van Beek, J. L., W. G. Smith, J. W. Smith, and P. Light. 1977. Plans and concepts for multi-use management of the Atchafalaya Basin. EPA - 600/3-77-062. U.S. Environmental Protection Agency, Las Vegas, Nv. 204 pp.

Stream Channel Renovation Methods to Mitigate Natural Resource Losses[1]

Chester A. McConnell[2]

Abstract.--Stream channel renovation methods, using a blend of hand labor crews with light equipment where possible and heavy equipment where necessary, are being used to minimize damages to natural resources on Wolf River, Tennessee. Methods, work guidelines and results are described.

Throughout time many streams have become obstructed to some degree with debris and sediment due to floods, wind storms and erosion. This is most common where the watershed has highly erosive soils and the floodplain is broad and flat. The long-term result is swamping and channel relocation. In some floodplains, channels have relocated many times. Unwise landuse in watersheds, and particularly in floodplains have increased these events. Timber, agriculture crops and structures in floodplains are often damaged. On occasions, fish and wildlife habitat may be adversely altered.

Various approaches have been used to maintain or improve stream capacity, including channelization. Due to the controversy associated with channelization, less severe methods are being tried which have less adverse impacts.

Tennessee's Wolf River had numerous obstructions caused by fallen trees and other debris and excessive sedimentation (fig. 1 and 2). A Soil Conservation Service project, using a blend of hand labor crews with light equipment where possible and heavy equipment where necessary, is renovating approximately 22 miles of this natural stream. Detailed guidelines (Appendix 1) were developed to identify the renovation method to be used at specific river segments, the debris to be removed from the channel and how and where to dispose of it, the riparian vegetation to be removed, and on which side of the stream the work was to be performed. A Biology Work Group, representating federal, state and county agencies and a private organization was formed to assure that work conforms with the guidelines.

Hand labor crews use chain saws, portable winches, boats and a small crawler tractor with winch to remove minor obstructions (fig. 3 and 4). Major blockages that span the channel for long distances and obstruct normal flow or force water out of the natural channel, are removed with dozers and draglines (fig.5). When trees on the river bank have to be cut, the stumps are left for bank stabilization and erosion control. These mitigation measures are being used to renovate the Wolf River so that it functions more in accordance with society's desire while still protecting and enhancing natural resource values (fig. 6 and 7.)

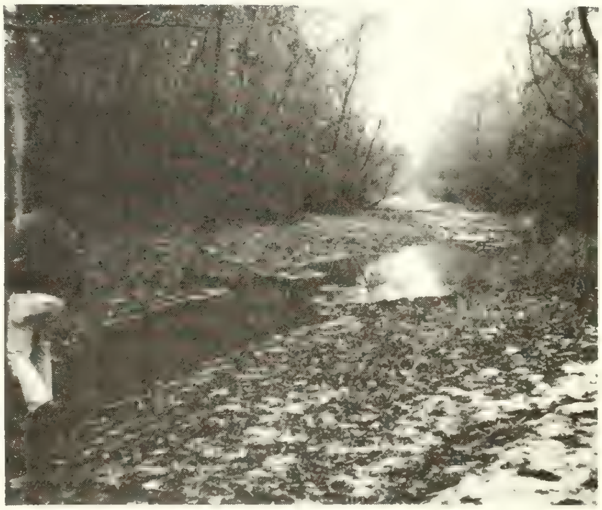

Figure 1.--Complete blockage of Wolf River by sediment. Water flow is forced into floodplain.

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[1] Poster summary presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Southeast Representative, Wildlife Management Institute, Lawrenceburg, Tennessee 38464.

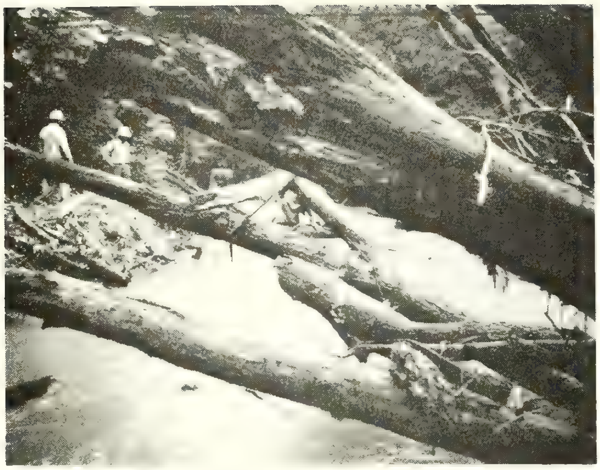

Figure 2.--Log jams trapped other debris and sediment at many locations on Wolf River.

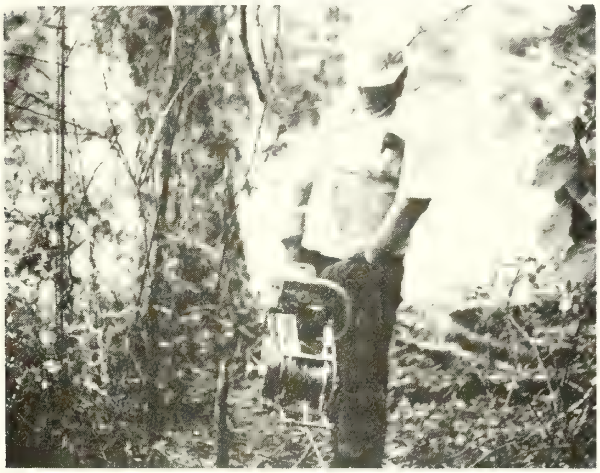

Figure 3.--Portable winch being used to pull small log from Wolf River.

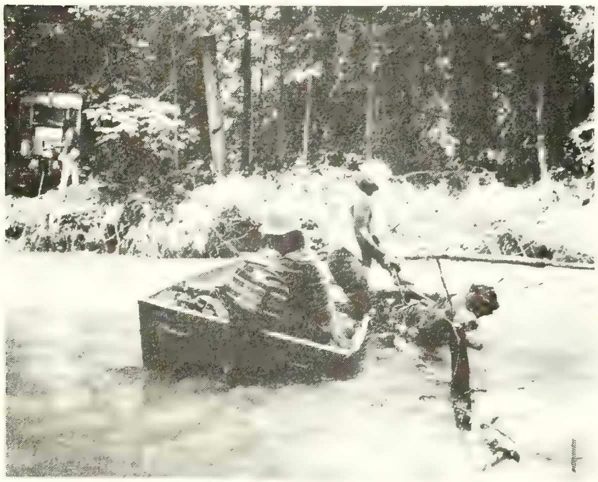

Figure 4.--Hand labor crew in jon boat hooking cable to log to be winched out by tractor.

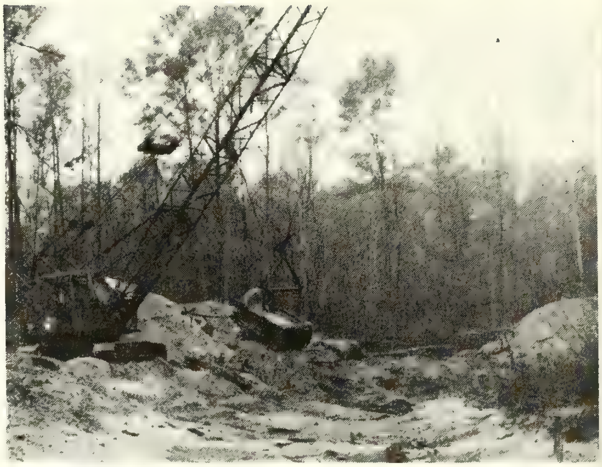

Figure 5.--Dragline removing debris and sediment from major blockage on Wolf River.

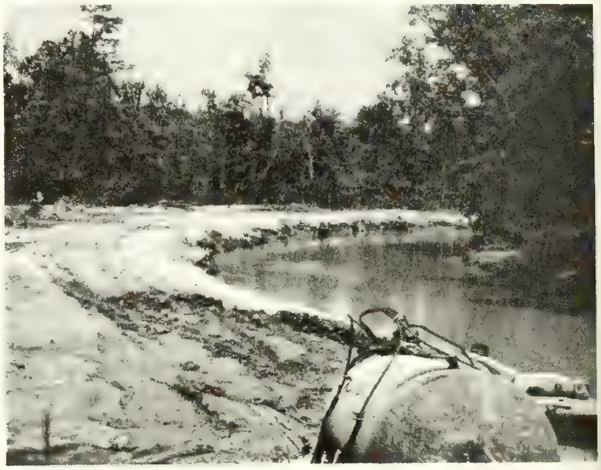

Figure 6.--Wolf River as it appeared just after a major blockage had been removed. Note trees remaining on one side and stumps on river bank.

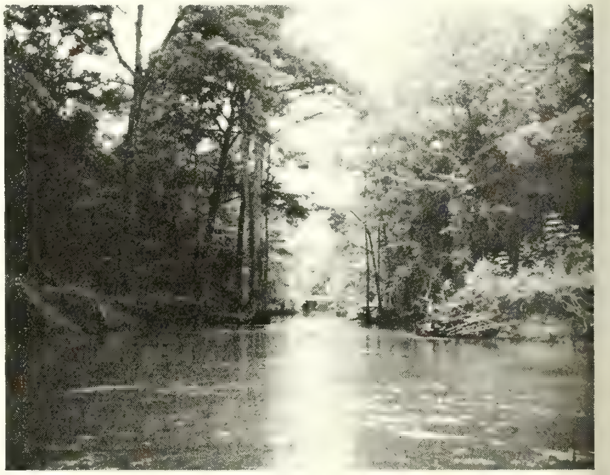

Figure 7.--Wolf River as it appeared just after obstruction removed by hand labor crew.

Appenxix I.--Clearing and snagging guidelines for Wolf River System.[3]

I. General guidelines.

No stream work, including bank clearing and excavation or removal of materials, should be allowed except at specific locations where significant blockages occur. Channel excavation and snag removal should be accomplished with the minimum clearing possible to provide access to the stream.

II. Materials to be removed from the channel.

A. Log jams. Only those log accumulations that are obstructing flows to a degree that results in significant ponding or sediment deposition should be removed.

B. Other logs.

1. Affixed logs. Isolated or single logs will not be disturbed if they are embedded, jammed, rooted or waterlogged in the channel or the floodplain, are not subject to displacement by current, and are not presently blocking flows. Generally, embedded logs that are parallel to the channel are not considered to cause blockage problems and will not be removed. Affixed logs that are crossways to the flow of waters in the channel and are trapping debris to the extent that could result in significant flooding or sedimentation may be removed.

2. Free logs. All logs that are not rooted, embedded, jammed or sufficiently waterlogged to resist movement by river currents may be removed from the channel.

C. Rooted trees. No rooted trees, whether alive or dead, should be cut unless:

1. They are leaning over the channel at an angle greater than 30° off vertical and they are dead or dying or have severely undercut or damaged root systems or are relying upon adjacent vegetation for support and it appears they will fall into the channel within one year and create a blockage to flows; or

2. their removal from the floodplain is required to secure access for equipment to a point where a significant blockage has been selected for removal.

D. Small debris accumulation. Small debris accumulations should be left undisturbed unless they are collected around a log or blockage that should be removed. (It is felt that small debris accumulations will not constitute a significant blockage to flows and upon removal of logs and other blockages under these guidelines and following completion of the project, the changed water velocities would remove and disperse these small debris accumulations so that no significant blockage of water flows will result.)

E. Sediments and soils. Major sediment plugs in the channel may be removed if they are presently blocking the channel to a degree that results in ponding and dispersed overland flow through poorly defined or nonexistent channels and, in the opinion of appropriate experts, will not be removed by natural river forces after logs and other obstructions have been removed.

III. Work procedures and equipment to be used.

A. Log removal. First consideration will be given to the use of hand operated equipment to remove log accumulations. When the use of hand operated equipment is infeasible, vehicled equipment may be used under the following restrictions and guidelines:

1. Water-based equipment (e.g., a crane or winch mounted on a small, shallow draft barge or other vessel) should be used for removing material from the streams. A small crawler tractor with winch or similar equipment may be used to remove debris from the channel to selected disposal points.

2. When it can be demonstrated that stream conditions are inadequate for the use of water-based equipment, the smallest feasible equipment with tracking systems that minimize ground disturbance will be specified for use. Larger equipment may be employed from non-wooded areas where cables could be stretched down to the channel to drag out materials to be removed.

3. Access routes for equipment should be selected to minimize disturbance to existing floodplain vegetation, particularly in the riparian zone. Equipment should be selected which will require little or no tree removal to maneuver in forested areas.

B. Rooted trees. Whether dead or alive, rooted trees selected for removal shall be cut well above the base, leaving the stump and roots undisturbed. Procedures for removing the felled portion will be the same as for other logs.

C. Log disposal - General. All logs or trees designated for removal from the stream or floodway shall be removed or secured in such a manner as to preclude their re-entry into the channel by flood waters. Generally, they will be transported well away from the channel and floodway and positioned parallel to the stream channel so as to reduce flood flow impediment. Where large numbers of logs are removed at one location (e.g., log jams), burning may be the most feasible disposal technique. Burying of removed material should not be allowed.

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[3] Guidelines developed by several government agencies and private organizations. Similar guidelines are being used on the SCS Chicod Creek Watershed project in North Carolina and are planned for two additional projects in Tennessee.

D. Sediment blockages. The magnitude of the blockage such as the one in the vicinity of Moscow, Tennessee, necessitates the use of conventional excavating equipment. This equipment should be employed in a manner which will minimize environmental damages.

1. Access routes for equipment should be selected to minimize disturbance to existing floodplain vegetation, particularly in the riparian zone.

2. Material disposal and necessary tree removal should be limited to one side of the original channel at any given location.

3. To the maximum extent possible, excavating equipment should be employed in the channel bed.

4. Where feasible, excavated materials should be removed from the floodplain. If floodplain disposal is the only feasible alternative, spoil should be placed on the highest practical elevation and no material should be placed in any tributary or distributary channels which provide for ingress and egress of waters to and from the floodplain.

5. No continuous spoil pile should be created. It is suggested that no pile exceed fifty (50) feet in length or width and a gap of equal or greater length should be left between adjacent spoil piles.

6. Spoil piles should be constructed as high as sediment properties allow.

7. The placement of spoil around the bases of mature trees should be avoided where possible.

IV. Reclamation measures.

All disturbed areas should be reseeded or replanted with plant species which will stabilize soils and benefit wildlife. Revegetation should be in accordance with recommendations of the Biology Work Group.

Photographic credit: Figures 1, 4, 6, 7-Chester McConnell, Wildlife Management Institute, Figures 2, 3-Mike Zeman, U. S. Soil Conservation Service; Figure 5, Willis Gainer, U. S. Soil Conservation Service.

Development of Wildlife Compensation Features at Water Resource Projects [1]

Andrew C. Miller[2]

Abstract. – A modified Habitat Evaluation Procedure was utilized to account for all terrestrial habitat modifications at two authorized lakes in early planning stages. Wetland creation, alterations in the flood pool, and maximal management techniques on any available project lands were considered. Use of this approach has resulted in development of more environmentally sound water resource projects.

INTRODUCTION

The Louisville District of the U.S. Army Corps of Engineers used new methodology, based in part on Habitat Evaluation Procedures (HEP) of the U.S. Fish and Wildlife Service (FWS), to analyze terrestrial habitat losses and gains caused by development of water resource projects. District personnel participated with FWS in these studies and performed further evaluation. The following discusses potential alterations to the terrestrial habitat at two proposed lake projects designed for flood control, recreation, water supply, and fish and wildlife. Big Blue Lake in Indiana and Louisville Lake in Illinois were authorized in 1968. Total authorized acreage is 20,950 acres for Louisville Lake (1,500 acres for mitigation), and 8,900 acres for Big Blue Lake (140 acres for mitigation).

In both studies existing conditions were determined by a triagency team of biologists from the Corps of Engineers, FWS, and the state wildlife agency. Habitat losses, as determined by the team, were expressed in habitat units (U.S. Fish and Wildlife Service, 1979). In both studies conducted by the District net osses caused by development of the lake were based upon differences between the "with" and "without" project condition; the latter was made by evaluation of agronomic and economic trends in the area.

HABITAT EVALUATION

Flood Pool

In the flood pool, unlike the conservation pool and construction area of a water resource project, losses are dependent upon lake characteristics and meteorological conditions. The flood pool at Louisville Lake (475 – 490 mean sea level [msl]) was separated into four distinct zones to more accurately assess impacts on vegetation by water fluctuation.

Delineation of these four zones was based upon examination of the flood pool at other lakes and evaluation of flood frequency data for this project. Based upon studies of other lakes (Broadfoot and Williston, 1973) most of the vegetation in the flood pool, which consists of red and pin oaks, hickory, juniper and sassafras, will be eliminated by flooding. It was determined that all vegetation in the lowest section (475 – 477.5 msl) of the flood pool will be quickly lost (42,769 units on 943 acres) because of wave action, erosion, and submersion. Woody vegetation in the second (477.5–482 msl) and third (482 – 487.5 msl) zones will be severely stressed, mostly reverting to annuals and shrubby growth within the first years of operation. Habitat values were projected to decrease by 40% and 30%, respectively, in these sections of the flood pool. The highest section of the flood pool (487.5 – 490 msl) should retain its current value. The entire flood pool, approximately 5,800 acres (265,000 units), displayed a loss of 35,000 units because of periodic flooding. Some losses were recovered by succession of agricultural lands to old fields. In further studies it was determined that use for hydropower, which increases water level fluctuations, nearly doubles the loss of terrestrial vegetation.

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Biologist, U.S. Army Corps of Engineers, Louisville, Ky.

Wetland Development

The average end method (Department of the Army, 1969) was used to predict potential wetland acreage created by sedimentation. This was estimated as the difference between total area at specific elevation intervals below summer pool for present and future conditions. Sedimentation, usually in the upper reaches of the lake, will increase area and habitat units over the life of the project. For Big Blue Lake it was calculated that sediment deposition will create 526 acres of potential wetland habitat by project year 100. At proposed Louisville Lake it was determined that 792 acres, yielding a total of 112,331 habitat units, will be produced by project year 100. In addition to standing timber, these areas should support hydrophytic vegetation which will supply both food and cover for aquatic and semiaquatic species. The value to be placed on these areas was determined by analysis of existing habitat conditions in the area and at nearby man-made lakes.

Recreation Lands

To maximize habitat units for these studies, a clustered recreation design was used. Tent sites, picnic grounds, and play areas were grouped closely in specific sections leaving portions of the recreation lands undeveloped. Various wildlife management techniques were integrated into the clusters and all areas not directly impacted by recreational activities. Trails, wildlife viewing areas and camping sites will be placed in conjunction with wildlife compensation features. Such an approach will be beneficial to game and nongame species in addition to providing high quality activities for both camper and day user. At the Louisville Lake project, which had 1,135 acres of available recreation land, it was determined that proper management of lands not directly needed for recreational facilities would show a gain of 20,936 units.

WILDLIFE COMPENSATION

Mitigation

At the Big Blue project the majority of the loss, 81,062 units as defined by the FWS HEP team, was compensated for by on-project wildlife management techniques. In three alternatives the team recommended various management procedures on most of the authorized recreation lands and purchase of up to 200 additional acres for wildlife. Subsequent to this analysis, however, the dam location was moved 1.3 miles upstream. After transposition to this new site the total deficit was determined to be 66,106 units. When it was discovered that none of the team's alternatives were economically justified, the District reduced the amount of management on a portion of the recreation lands and "clustered" the facilities to maximize habitat value. After these changes had been incorporated, it was found that the project as redesigned provided 59,670 units, or approximately 90% of the adjusted loss (66,106) in units.

At Louisville Lake, by applying maximal management techniques on authorized mitigation, available recreation, and fee acquisition lands, the Louisville District calculated that 253,598 units, 88% of the deficit, was provided by the authorized project. The Illinois Department of Conservation, which did no have the resources to manage additional lands, concurred. The U.S. Fish and Wildlife Service, however did not agree with wildlife management on recreation and fee acquisition lands and rejected the use of the "without" project analysis in this study. They recommended purchasing 5,813 additional acres for wildlife

Enhancement

For the Louisville Lake study, the Corps o Engineers, with the Illinois Department of Conservation, developed an enhancement plan for wildlife. The following features, to be developed exclusively on project lands, were planned: a 400 acre subimpoundment in the flood pool, nursery ponds, spawning bars artificial squirrel and duck nests, succession control wildlife plantings, and development of ponds in the uplands. Within one section of the flood pool a serie of small ponds will be constructed to provide food fo waterfowl, wading birds, and aquatic furbearers. These enhancement features, if acceptable to the State o Illinois, will cost approximately one million dollars and be cost shared 75% Federal and 25% non-Federal

SUMMARY

The Louisville District has participated in two HEP studies with FWS at authorized lake projects in the early planning stages. No new land purchases have been authorized, although FWS recommended additional lands for mitigation based upon their results with HEP. The principles of HEP have been used by this District to improve existing project lands fo wildlife.

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The Inertia and Resiliency of a Mountain Stream to Construction Impact[1]

Leo D. Cline[2], R. A. Short[2], J. V. Ward[3], and C. A. Carlson[4]

Abstract.--Predictive indices of inertia (ability to resist disturbance) and resiliency (ability to recover from disturbance) were applied to a mountain stream subjected to highway construction activities. Expected inertia values were exceeded as demonstrated by physical, chemical, and biological parameters. Application of ecological principles elucidates the discrepancy between predicted and observed responses.

INTRODUCTION

A means of evaluating the potential for fish and wildlife mitigation prior to project development is needed. One such proposed method was outlined by Cairns (1976) and refined by Westman (1978). Predictive indices of inertia (ability to resist disturbance) and resilience (degree, manner, and pace of restoration following disturbance) were applied to a high elevation stream subjected to highway construction activities. These predictions were compared with the actual response of physical, chemical, and biological parameters which were measured on 47 sampling trips between May and October from 1975 to 1977. Data presented below are only summary or representative in nature due to limited space. Publication of complete results are planned as a Gen. Tech. Report by the Rocky Mountain Forest and Range Experiment Station.

STUDY AREA

Joe Wright Creek is a small high mountain stream located approximately 113 km northwest of Fort Collins, Colorado and which roughly parallels State Route 14 which was recently re-aligned and paved. The stream begins on Cameron Pass (3132 m elevation) and flows approximately 22.2 km with an average slope of 3.0% before entering the Big South Fork of the Cache La Poudre River (2545 m). The drainage basin comprises 95.8 sq. km, 73% of which is wooded; soils are primarily granitic (Fugua 1974).

METHODS

Water chemistry analyses followed procedures in Standard Methods (APHA 1971).

Macroinvertebrates were sampled with a 700 µm mesh Surber sampler. In 1975 and 1976, six replicates were taken in fast water (erosional) zones of riffles. In 1977, four replicates each were taken in fast water and slow water (depositional) zones.

Eight sampling sites were located between 3045 m (site 1) and 2716 m (site 8). Sites 1, 3, 5, and 7 were not subjected to highway construction activities while 2, 4, 6, and 8 were altered directly or indirectly.

Inertia index values were calculated in the following manner (see Cairns 1976 for full discussion):

Factor	Rating	Score
Indigenous organisms accustomed to variable environment	Moderate	2
High structural and functional redundancy	Moderate	2

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979. The research reported here was supported in part by the Forest Service, U.S. Department of Agriculture, through the Eisenhower Consortium for Western Environmental Forestry Research and is published as Eisenhower Consortium Journal Series Paper No. 41.

[2] Research Assistants, Department of Zoology and Entomology.

[3] Associate Professor, Department of Zoology and Entomology.

[4] Professor, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado 80523.

Inertia Factor (cont.)	Rating	Score
Mixing capacity	Moderate	2
Proximity to ecological threshold	Good margin of safety	3
Regional management capabilities	Moderate	1.5
Total score (multiplicative):		72

A total score of 400+ indicated high inertial stability; 55 to 399, fair to good inertial stability; less than 55, poor inertial stability (Cairns 1976). Thus, resistance to disturbance was expected to be fair.

Resilience index values were calculated in the following manner:

Factor	Rating	Score
Existence of nearby epicenters	Good	3
Transportability of dissemules	Good	3
Condition of habitat	Mod.-Good	2.5
Presence of residual toxicants	Small amounts	3
Chemical-physical water quality	Normal	2.5
Regional management capabilities	Moderate	1.5
Total score (multiplicative):		253

A total score of 400+ indicated that the chance of recovery were excellent, 55 to 399, fair to good; less than 55, poor (Cairns 1976). Thus, resiliency was expected to be fair to good.

RESULTS AND DISCUSSION

Studies of selected chemical parameters (table 1) indicated that total dissolved solids pH, free and bound carbon dioxide, dissolved oxygen, and water temperature had high inertia. For example, dissolved oxygen values were virtually the same at sites 1 and 2; 3 and 4; 5 an 6; and 7 and 8. Total suspended solids displa lower inertia, but resilience was high as exemplified at sites 1 and 2 (fig. 1).

The response of substrate particle size composition to disturbance varied with current velocity. Prior to construction, site 2 slow water areas were comparable to those of site 1. During construction, clay to gravel sized particles covered the cobble and gravel already present at site 2 (fig. 2). Five weeks after construction, a substantial portion of all but the finest particles in slow water areas at sit 2 had been removed. In contrast, fast water substrates were virtually the same prior to, during, and following construction. Thus,

Table 1. Chemical parameters (mean values), Joe Wright Creek, Colorado. (U: Unimpacted site; I: Impacted site)

Parameter/Site	1(U)	2(I)	3(U)	4(I)	5(U)	6(I)	7(U)	8(I)
Total suspended solids (mg/l)								
1975	1.3	---	---	---	3.2	15.8	10.9	7.7
1976	2.5	---	---	---	23.2	15.6	8.4	9.8
1977	16.7	94.7	3.4	80.7	---	---	---	---
Total dissolved solids (mg/l)								
1975	33.4	---	---	---	34.7	35.3	30.9	34.4
1976	16.5	---	---	---	19.3	26.4	42.6	29.4
1977	33.2	30.6	25.4	30.5	---	---	---	---
pH (mode)								
1975	7.2	---	---	---	7.2	7.2	7.2	7.2
1976	7.1	---	---	---	7.2	7.2	7.2	7.3
1977	7.3	7.2	7.2	7.2	---	---	---	---
Free carbon dioxide (mg/l)								
1975	1.4	---	---	---	1.4	1.3	1.5	1.0
1976	1.4	---	---	---	1.6	1.5	1.8	1.7
Bound carbon dioxide (mg/l)								
1975	13.0	---	---	---	12.0	12.1	9.7	10.8
1976	10.2	---	---	---	11.3	11.1	9.2	10.0
1977	10.8	9.9	11.8	11.6	---	---	---	---
Dissolved oxygen (mg/l)								
1975	9.5	---	---	---	9.6	9.3	8.6	8.6
1976	9.2	---	---	---	9.0	8.9	8.2	8.2
1977	11.8	11.1	10.3	10.1	---	---	---	---
Temperature (^{o}C)								
1975	1.4	---	---	---	2.1	3.5	7.5	7.6
1976	2.5	---	---	---	3.4	4.8	8.3	8.4
1977	3.7	4.9	7.1	8.6	---	---	---	---

substrate response to disturbance displayed low inertia and moderate resilience in slow water areas. Fast water substrate displayed distinctly higher inertia.

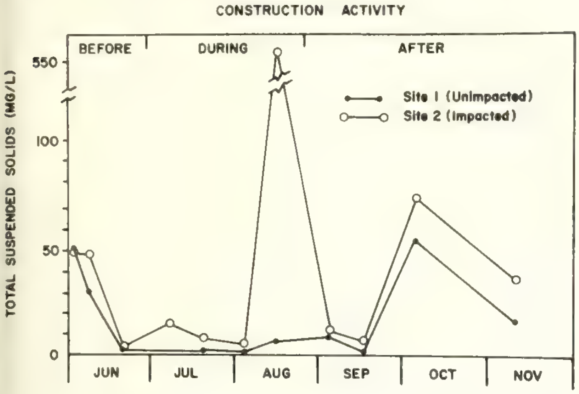
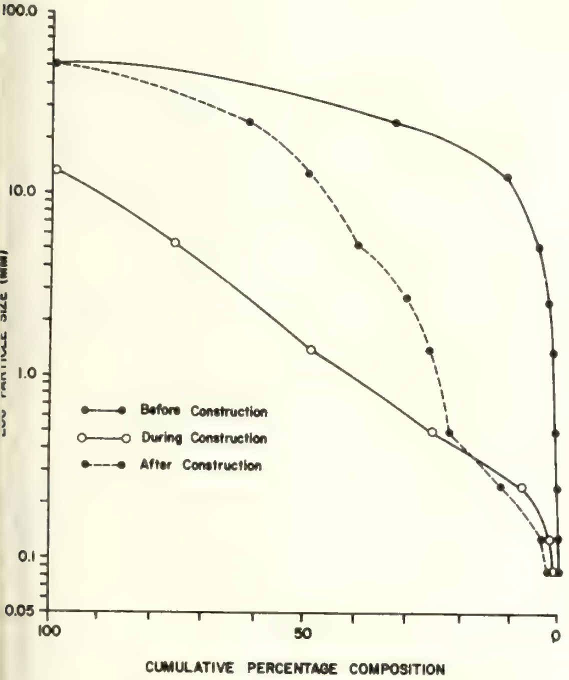


Figure 1.--Total suspended solids, Joe Wright Creek, Colorado, 1977.



igure 2.--Substrate particle size composition, site 2, slow water area, Joe Wright Creek, Colorado, 1977.

Macroinvertebrate density values (table 2) indicated that in 1975 and 1976 when sampling was restricted to fast water areas, there was little or no discernible impact due to highway construction. For example, in 1975, macroinvertebrate densities at sites 5 and 6, as well as 7 and 8, were virtually identical. Thus, high inertia was apparent. In 1977, however, the macroinvertebrate community displayed lower inertia possibly because of the lower discharge and lesser gradient of the stream section sampled (sites 1-4). Furthermore, there was lower inertia and resiliency in slow water areas than in fast water areas at site 2 (fig. 3).

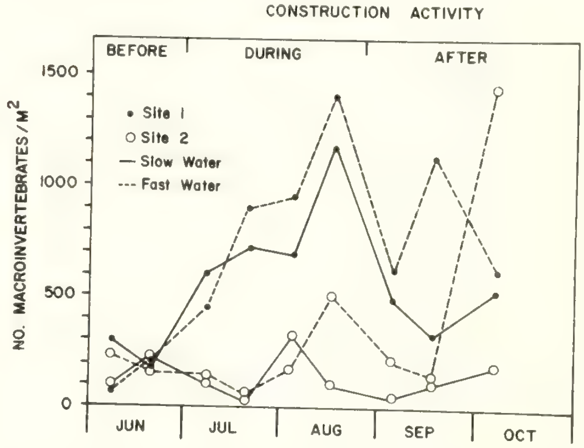


Figure 3.--Macroinvertebrate density (No./m^2), Joe Wright Creek, Colorado, 1977.

CONCLUSIONS

As Westman (1978) indicated, evaluations of this sort are in their infancy; in addition, some subjective judgments and descriptive measures were applied which require further testing. In this study, higher inertia and resiliency were found than were predicted. Cairns _et al_. (1977) indicated that information about impacts on lotic ecosystems was relatively scarce in comparison with other ecosystems. Joe Wright Creek, a headwater stream with a short ice-free season, was thought to be particularly susceptible to perturbation. In actuality, the system appeared to be partially self-mitigating. Factors which probably contributed to this response include: 1) the

able 2. Macroinvertebrate mean density (number/m^2), Joe Wright Creek, Colorado. (U: Unimpacted site; I: Impacted site)

ear/Site	1(U)	2(I)	3(U)	4(I)	5(U)	6(I)	7(U)	8(I)
975 (fast water)	1477	----	----	----	931	965	1258	1264
976 (fast water)	776	----	----	----	827	631	308	599
977 (fast water)	697	346	702	402	----	----	----	----
977 (slow water)	560	147	531	297	----	----	----	----

presence of a relatively steep gradient and virtual absence of pools, thus maintaining steady stream flow across the width of the channel and minimizing sedimentation, 2) the presence of macroinvertebrate populations in tributaries and above construction areas for recolonization, 3) the impacts were of relatively short duration, 4) the impacts directly affected only a short stream section, and 5) the impacts were not an annual event at the same location.

A general conclusion of the three years of study is that spring runoff and spates ameliorated short-term construction impacts to localized stream sections. Although slower recovery was evident in the macroinvertebrate community, biological phenomena generally lag behind physicochemical changes. Provided that suspended solids and substrate return to normal, the benthos may also recover.

In concurrence with the data of Stauffer et al. (1978), there was no correlation between inertia and resiliency. In addition, different parameters responded in different ways. Perhaps physical or chemical parameters should be evaluated separately from biological ones since their resistance to and recovery from disturbance may be different. Temporal aspects may be important in the calculation of inertia and resiliency, yet there is no provision for this in the indices.

During the two years since the highway construction study was completed, reservoir construction has commenced on Joe Wright Creek. Long-term construction activity over a large stream section coupled with the loss of some tributaries (by virtue of impoundment) has resulted in extended and increased suspended solids levels, large increases in the percentage of sands and silt in stream substrate and great reduction of macroinvertebrates in some locations.

Resilience is expected to be considerably lowered by a number of factors. The creation of an impoundment not only eliminates some tributaries but also precludes downstream drift of lotic organisms from unimpacted areas. Dam operation is expected to modify the discharge regime and short-term spates may be eliminated, thus altering the normal flushing which has allowed Joe Wright Creek to recover fairly quickly from disturbance. Finally, thermal alterations are expected since the dam will release water from the hypolimnion. Therefore, the impoundment will greatly modify ecological conditions of the receiving stream (Ward and Stanford 1979) and alter factors such as the flushing capability and recolonization phenome thereby influencing resiliency.

ACKNOWLEDGMENTS

R. L. Bottorff and R. G. Dufford are thanked for assistance with some of the field and laboratory work. Research was supported by the Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S.D.A. through the Eisenhower Consortium for Western Environmental Forestry Research. L. D. Cline was partially supported by a Conservation Fellowsh from the National Wildlife Federation.

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The Use of the U.S. Fish and Wildlife Services's Habitat Evaluation Criteria Handbooks in the Mitigative Process[1]

Yvonne B. Weber[2]

The U.S. Fish and Wildlife Service has developed procedures for the evaluation of impacts that result from Federally funded or licensed water resource development projects, as required by the Fish and Wildlife Coordination Act. These procedures also have application under the National Environmental Policy Act and the Principles and Standards. Originally, these procedures were published as the Ecological Planning and Evaluation Procedures (EPEP or EP[2]) in 1974, and were subsequently shortened, revised, and published as the Habitat Evaluation Procedures (HEP) in July 1976 and March 1979.

The procedures have been applied throughout the Service on Corps of Engineers, Soil Conservation Service, and Bureau of Reclamation projects. With the increased emphasis on environmental concerns, and in light of the President's Water Policy Message of June 6, 1978, these procedures will receive increasing application in the future.

To implement the Habitat Evaluation Procedures, Habitat Evaluation Criteria Handbooks are being prepared in cooperation with numerous state and Federal agencies around the Nation. During the next several years, approximately 65 terrestrial, 25 aquatic and 25 coastal/estuarine handbooks will be developed on a regionalized basis for use in evaluating fish and wildlife habitat using HEP. These handbooks quantify the life requisites of fish and wildlife species, and describe the essential habitat characterisitcs of the vertebrate species present, thereby providing documentation and criteria for describing baseline conditions, assessing project alternatives, and planning for mitigation.

Each handbook provides site specific fish or wildlife data. The indices of habitat suitability (HSI scores) derived by use of the handbook are used within HEP for calculations of environmental impacts and to determine mitigation and compensation measures needed to replace habitat losses due to the proposed project.

Review draft copies of five Terrestrial Habitat Evaluation Criteria Handbooks will be on display, with posters that describe their application. Operational draft copies of the five handbooks on display will be available in 1980. Inquiries for additional information may be addressed to the author.

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[1] Poster Presentation at The Mitigation ymposium, Colorado State University, ort Collins, Colorado, July 16-20, 1979.

[2] Handbook Coordinator, U.S. Fish and ildlife Service, 2625 Redwing Road, Fort ollins, Coloardo 80526.

Computerized Evaluation of the Wildlife Habitat Option as a Post-Mining Land Use[1]

M. Douglas Scott[2]

Abstract.--When coal surface-mined land is reclaimed in the Northern Great Plains, property owners usually ask that it be returned to a higher economic use. The CLAIM computerized reclamation planning system encourages companies to compare reclamation costs for different land uses. A CLAIM analysis reveals that the wildlife reclamation option is often the most inexpensive.

Land in the Northern Great Plains of eastern Montana, northeastern Wyoming, and western North Dakota is primarily managed for livestock grazing or small grain farming. Wildlife management is, unfortunately, only a secondary land use on most properties in the region. During the last 20 years, much coal was found in the Northern Great Plains, and mining companies acquired surface rights so that they might remove the resource, which was owned by a variety of private and governmental entities (National Academy of Sciences 1974). The companys' main interest was in obtaining access to the coal, and surface ownership often has remained with private individuals or corporations, who continue to manage the property after mining and reclamation is completed (Scott and Terrel 1976).

People who own the surface rights to coal lands historically have had some input to the reclamation plan for the property, and now this is mandated by the Federal Surface Mining Control and Reclamation Act of 1977 [Public Law 95-87, Sec. 508(a)(3)]. Since these owners obtain their income from agriculture, they usually are eager to have the reclamation process 'improve' the land from the standpoints of reduced topographic relief and increased forage and grain production (Morgan 1973, Lynott 1977). Because the company obtains access from surface owners, mine managers are responsive to their desires, and reclamation for agriculture usually takes place, even though the practice may be detrimental to wildlife populations that existed before mining started. Also, rigid state and federal reclamation laws, and red tape, strong influence companies to reclaim for row crops o pasture (Terrel and Shinn 1977).

In order to mitigate this institutional bias toward reclaiming only for agriculture in the Northern Great Plains, company and regulatory personnel should be encouraged to evaluat other land use options. Since today's manager must analyze many baseline data before arrivi at a final land use decision, the computer, wi its speed and accuracy, should be a tool which can be used to make quick comparisons of recla mation options (Scott 1978). An initial answe to these needs, a computerized land reclamati planning system, called CLAIM,[3] has been devel oped (Scott 1979). The system is now designe just for the Northern Great Plains, but it ma be adapted to other regions as well. Programm of the system was done with the users' convenience in mind first, so that its simplicit of operation would encourage them to use CLAI to evaluate reclamation alternatives. Mining and environmental data are entered into the system in an interactive fashion (the user answers questions posed by the computer), and managers without prior computer experience ca operate it after only 1-2 hours of briefing.

The basic output of CLAIM is a ranking o the relative feasibility of reclaiming a parc of land to each of five land uses, which correspond closely to land use options discussed the new Federal surface mining laws. These o tions are: cropland, rangeland (composed mos of native species), wildlife management, recreation (usually water-oriented), and high human occupancy (such as for homes or businesses). Another output of the system is a list of techniques and costs for reclaiming the land to each of the five land uses.

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[1] Poster presented at The Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

[2] Research Associate, Office of Research and Development, Montana State University, Bozeman.

[3] Creation of the CLAIM system was funded through a cooperative agreement between the U. Forest Service Surface Environment and Mining (SEAM) program, and the Montana State Univers Office of Research and Development.

The CLAIM system has been used to analyze many sets of data from several mining areas in the Northern Great Plains. Results of some of these evaluations are presented in table 1.

Table 1.--Costs per acre of reclamation for five land uses at four different sites, as computed by CLAIM

Type of	Reclaimed land use				
Mine Site	Crop.	Rge.	Wild.	Rec.	Homes
Wyoming range (truck & shovel)	$4596	3481	3365	3913	4622
Montana range (dragline)	5333	4483	4433	5035	5486
Montana range-endangered animal (dragline)	5460	4437	4387	4989	N.A.[1]
N. Dakota cropland (dragline)	7261	5886	5835	6764	7375
Mean	5663	4572	4505	5175	5828

[1] This use is incompatible with reclaiming land to endangered animal species' habitat.

The general trend revealed in the table (and from other analyses not shown) is that the wildlife management land use is often the cheapest for a company to create through reclamation, whereas cropland and high use are much more expensive goals. Besides saving money, the wildlife management option provides the company with much more public relations benefit in local communities. People in towns generally are more interested in seeing their recreational opportunities expand in relation to wildlife, rather than having the mine surface owner (which may be a company subsidiary) make a higher income from more productive land (Scott and Terrel 1976).

The private surface owner cannot be completely forgotten, however, in that he still must make a living. Hunting and other forms of wildlife-related outdoor recreation do have definite economic values (Clawson and Knetsch 1966, Leitch and Scott 1977), and at least two studies have found that wildlife management may produce an income equivalent to cattle ranching on the same property (Scott and Terrel 1976, Martin and Gum 1978). If the surface owner feels he must make an income from traditional agricultural sources, wildlife habitat can still be established on property boundaries, around buildings, or along watercourses. When this is the case, the CLAIM Computerized system can quickly and economically evaluate the feasibility of creating these small wildlife areas, so that wildlife populations removed by mining may be reestablished.

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Ecological Disturbances[1]

Edward J. Rykiel, Jr.[2]

Abstract.--Expected response of ecological systems to disturbance is usually the basis for mitigation decisions. Information about distrubance characteristics is essential for estimating this response because of adaptations to disturbance. The following set of characteristics is proposed: type, initial predominant effect, frequency, intensity, duration, reliability, level, and scale.

INTRODUCTION

Mitigation implies alleviation of harmful effects; and in the context of fish and wildlife, that these resources will be damaged unless corrective action is taken. Central concerns are to prevent irreparable harm and to limit damage to acceptable levels. Effective mitigation decisions depend on at least three basic elements: 1) specific biological knowledge, 2) ecological responses to disturbance, and 3) disturbance characteristics. The focus of this paper is on disturbance characteristics.

The major ideas proposed are that ecosystems, communities, and species are adapted to disturbances with specific characteristics (Connell 1978) and that ecological stability is threatened or reduced to the extent that the characteristics of man-made disturbances diverge from those of natural disturbances.

MITIGATION AND ECOLOGICAL STABILITY

Mitigation concepts are related to ecological stability concepts. Stability consists of two related aspects, constancy (ability to resist change) and recoverability (ability to return to pre-existing conditions after disturbance) (Holling 1973, Van Voris 1976, Webster et al. 1974). Mitigation is invariably designed to maintain constancy by avoiding alteration of the ecosystem, community, and species, and to promote recoverability by reducing reestablishment time.

Two primary concerns are expressed by mitigation proposals. The first is that a disturbance will cause the existing ecosystem and component species to be replaced by another "less desirable" ecosystem with different component species. This concern is often related to a few most-favored species. The ecosystem will change due to the disturbance. Here the underlying issue is constancy.

The second concern is that the time involved to restore pre-existing (or natural) conditions is too long to be acceptable. Essentially, a long-term successional process is set in motion by the disturbance (Connell and Slayter 1977). The few most-favored species will be absent until succession reaches a stage where suitable habitat again develops. Here the issue is recoverability.

Various degrees of these concerns may be expressed in specific circumstances. The fear most often voiced is that the disturbance will destroy any inherent ecological ability to recover to pre-existing conditions, and thus result in irreversible change, i.e. one ecosystem is replaced by another. However, the aspects of constancy and recoverability are linked inseparably even though one may be more important than the other in a particular case.

Neither mitigation nor stability has much meaning for management purposes without reference to a disturbance (Loucks 1970). My purpose is to propose a set of characteristics which can be used to define the nature of a disturbance explicitly. Such characteristics are necessary to make sense of ecological stability; and, when combined with specific biological knowledge and ecological responses to disturbance, provide sufficient information to plan mitigation.

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DISTURBANCE CHARACTERISTICS

An approximation of the information necessary to characterize a disturbance is given in Table 1. Type is intended to provide specific information about the agent of disturbance. The agent may be animate or inanimate. Examples (not fully specified) are fire, coal mining, and grazing.

Table 1. Disturbance characteristics

Characteristic	Definition	Examples		
1. Type	General Description - Agent	Severe Winter	Fire	Coal Mining Surface
2. Initial Predominant Effect	Major Short-term Effect	Mule Deer Starvation	Community Structure Destroyed	Ecosystem Destroyed
3. Frequency	Number of Occurrences	Once in 10 Years	Once in 75 Years	Once
4. Duration	Length of One Occurrence	6 Months	6 Days	3-60 Years
5. Intensity	Severity	Population Reduced 50%	Biomass Reduced 85%	Biomass Eliminated
6. Reliability	Recurrence Probability for Specified Time Frame	0.5 for 10 Years	0.8 for 75 Years	0.001
7. Level	Structural Echelon	Species	Community	Ecosystem
8. Scale	Extent of Effect	3 States Affected	10,000 Hectares	1,000 Hectares

Initial predominant effect is intended to indicate the major short-term effect of a given disturbance type on the ecosystem-community and component species. The disturbance can be distributed or targeted. A distributed impact is one which affects a large number of species comprising the community. This kind of impact can also be viewed as one in which the time lags involved in propagating the disturbance throughout the ecosystem are minimal. A targeted impact is one which affects only one or a few species at the outset, and can also be viewed as involving fairly long time lags before effects are propagated throughout the ecosystem.

Frequency, duration, and intensity are important because they specify the degree of ecosystem exposure to a disturbance (Connell 1978). Frequency indicates the number of times a disturbance occurs in a specified time interval. Duration is the length of time the disturbance lasts during a single occurrence. Intensity is a measure of severity. An appropriate time interval depends on ecosystem-community dynamic behavior and the investigational purpose. Ecosystem and community time cannot be ignored even though the purpose of a particular study justifies shorter or longer observation periods. The concept of r- and k- selected species may be an appropriate basis for choosing ecosystem-community time frames. Population dynamics would be appropriate for choosing a species level time frame. Frequency and duration of a disturbance would then be determined relative to these time periods.

Reliability is intended to indicate the probability of recurrence of the disturbance at the ecosystem-community and species time scales. For example, if the community time scale is fifty years and the disturbance occurs at least once in every fifty year interval, then the disturbance is reliable to the community. This measure will differ, perhaps considerably, from predictability of disturbance at time intervals differing from ecosystem-community or species time. The key idea is that ecosystems, communities, and species are best adapted to natural disturbances because these are reliable on the appropriate time scale.

Level is intended to indicate the ecological echelon at which the disturbance effect is considered. Level is usually considered to relate to the sequence: organism, population, community, ecosystem, ecoregion, biome, and biosphere. Other echelons may also be useful. At the species level, higher level effects may be disregarded because they are less evident or difficult to measure. On the other hand, a general disturbance may be non-specific and multi-level, and therefore regarded as an ecosystem disturbance.

Scale is intended to gauge the scope of a disturbance by indicating the size of area affected, number of organisms, species, communities, etc. which are affected, and the interrelation of affected and non-affected areas. Scale also should reflect cumulative effects of a number of small scale disturbances.

When the characteristics discussed are compiled for a number of disturbances, a "disturbance field" within which ecosystems are organized may emerge. Some events in this field, although we call them disturbances, are really normal events in natural history and maintain certain ecological qualities. Ecological systems are adapted to these kinds of disturbances. Recovery mechanisms such as ecological succession are not destroyed but stimulated by these disturbances. In fact, a disturbance may play a key role in keeping an ecosystem at a particular stage of development. When the characteristics of these "natural disturbances" are known, we are in a much better position to anticipate the results of man-made disturbances, to determine if mitigation is necessary, and if so, to appraise the extent of required mitigation measures. Man-made disturbances are least harmful when their characteristics correspond to natural ecological disturbances.

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A Structural Vegetation Classification for Inventory and Habitat Assessment [1]

Jane Bunin and William Moir[2]

This easy-to-use, hierarchical classification is based upon only structural features of existing vegetation which can be learned quickly by those who are not botanists or ecologists or may be unfamiliar with local vegetation or flora. It can be used on information ranging from remote sensing to ground based data. It is especially suitable where ecological or floristic systems are impractical, unavailable, or too expensive.

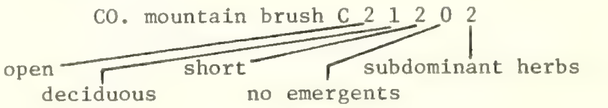
This hierarchical vegetation classification system is designed for vegetation inventory, habitat assessment, resource allocation, or land-use planning. It is especially suitable where ecological or floristic systems are impractical, unavailable, or too expensive to use. The upper level characteristics in the classification are large-scale and discernible by remote sensing. The descriptors at or below the 3rd to 5th levels usually require ground-based data.

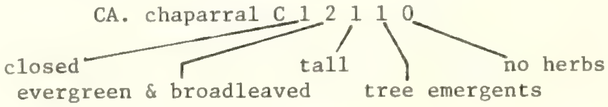
The classification is based upon the structure of current vegetation. The major structural characteristics used in the system include life-form types, canopy cover, leaf shape and persistence, and height of the vegetation. Because changes in life-form dominance and vegetation structure are very likely to have profound significance for wildlife, habitat assessments utilizing these characters are a good tool for wildlife managers. Current vegetation is used as contrasted to potential or climax vegetation. The use of current vegetation best suits the general purpose: To be an easy-to-use tool which is accessible to non-botanists and to those persons unfamiliar with local vegetation or flora, and to be a tool independent of ecological assumptions or taxonomic sophistication on the part of users.

We found that the one other hierarchical classification system based upon structural features of current vegetation (Fosberg 1967) was not designed for temperate regions, does not extend down to detailed levels, has some problems in application, and has, in fact, been little used. Other structural vegetation classification systems we studied included ecological or floristic characters, or were not hierarchical.

The classification we designed has seven initial categories: A. Closed Forest, B. Open Forest, C. Scrub, D. Dwarf Scrub, E. Herbaceous, F. Non-Vascular, and G. Non-Vegetated. These categories are further subdivided by cover, leaf characteristics, vertical structure, and other features. The number of subdivision levels used in the different categories varies with their complexity.

To summarize the vegetation classified by this system, we use a compact notation which consists of a letter plus a number of digits equal to the number of levels. Here are two scrub examples:





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[1] Paper presented at The Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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The poster presentation shows maps, photographs, or drawings exemplifying each of the six major categories A to F. Handouts include a working draft of the classification which contains a glossary of all technical or special terms.

Some examples from our poster display illustrate how disturbed habitats may differ in vegetation structure from undisturbed ones.

Old-growth (about 900 years) fir forests on Mt. Rainier are: Closed, tall, needleleaved evergreen forests with an irregular canopy profile; with a complex understory having closed layers of shrubs, herbs, non-vasculars and epiphytes; and with special structural features such as abundant downed logs and snags.

Contrast these forests to nearby fire-initiated young growth (about 100 years): Closed, tall, needleleaved evergreen forests with a smooth canopy profile; with a simple understory having some shrubs and a closed herb layer; and with occasional emergent snags.

Consider a relatively undisturbed Colorado mixed-grass prairie: Closed, medium-height, perennial graminoid vegetation with occasional shrub emergents and no non-vascular plant cover.

If overgrazed for several years, the same site might have: Open, short, mixed graminoid-forb perennial vegetation with abundant shrub emergents and no non-vascular plant cover.

A dwarf shrub example demonstrates how different scales and levels of information are easily accommodated. With a small-scale method such as aerial photography, a Colorado alpine willow community would be identified as "Closed deciduous dwarf scrub". Ground reconnaissance produces more information: "Closed deciduous creeping dwarf scrub with no emergents". Finally, detailed ground-based data classifies the same community as: "Closed deciduous creeping dwarf scrub with no emergents, with codominant herbs, and a sparse non-vascular layer."

This hierarchical classification, based upon the structure of current vegetation, is now being tested against specific vegetation data sets. We expect to revise the system as we receive comments concerning its strengths and weaknesses. We welcome yours.

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WILDMIS—A Tool for Impact Assessment and Mitigation Planning[1]

Kenneth R. Russell[2]

Abstract.--WILDMIS is a system that supplies information upon which to base mitigation negotiations and plans, land lease terms or mine development plans. Quantified production objectives must be set for each wildlife species of concern. The system estimates changes in population size after either adverse or enhancing habitat changes, and estimates the amount of money needed to reach a given wildlife production objective.

WILDMIS (Wildlife Management Information System) supplies information upon which to base mitigation negotiations, public land lease terms or mine development plans. The final output is an estimate of the cost for replacement, through wildlife management actions, of wildlife lost as a consequence of any proposed physical project or land use change. Intermediate products of WILDMIS include site-specific cost and benefit estimates associated with alternate wildlife management actions, species population density estimates, probabilities for occurrence of high and low species population densities, and quantitative descriptions of relevant environmental features.

WILDMIS utilizes three discrete and newly developed computer programs: EIDA, a mapping system; PATREC, a habitat evaluation system; and MANALT, a wildlife management evaluation system. EIDA (Ecological Information and Data Analysis), PATREC (pattern recognition) and MANALT (management alternatives) are based on concepts new to wildlife management. An interactive computer terminal, accessories, and CYBER 172 computer or equivalent are required for a fully automated use of WILDMIS, but all except the MANALT step can be performed manually. The system is suitable for use by either agencies or industry. Personnel training is necessary. Successful use of WILDMIS is contingent upon quantified wildlife production objectives being set, by priority, prior to any attempt to develop mitigation plans.

PATREC utilizes a probability-of-occurrence approach adapted from medical diagnostic procedures and a market prediction formula to estimate likely wildlife population densities. Probabilities are derived by identifying habitat features present at several sites where high and several sites where low population densities of the species of interest are found. MANALT contains a "universal" list of possible wildlife management actions, unit costs and expected benefits associated with each action, cost and benefit adjustment options to fit the circumstances or perceptions of the system user, a "probability of success" feature, and a comprehensive index value to help identify optimum choices among candidate management actions.

WILDMIS is a result of a 3-year effort to identify mitigation goal alternatives for oil shale development. WILDMIS will be used (1979-82) for developing alternative wildlife mitigation plans in conjunction with phosphate development in southeastern Idaho. WILDMIS is a product of the Colorado Cooperative Wildlife Research Unit, Colorado State University through a contract with the U.S. Fish and Wildlife Service, Office of Biological Services, Western Energy and Land Use Team. The same contractor funded development of EIDA. EIDA is composed of three major subsystems; WAMS, a geographic data entry system, MOSS, a geographic information display and analysis system, and MANAGE, a data base management system. PATREC, through a contract between the Unit and the U.S. Fish and Wildlife Service, Ecological Services, Project Impact Evaluation Group, is undergoing (1977-1980) field testing and evaluation of its potential to enhance the Habitat Evaluation Procedure (HEP) presently in use in the Fish and Wildlife Service.

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[1] Poster presentation at the Mitigation Symposium, Fort Collins, Colorado, July 17-19, 1979.

[2] Leader, Colorado Cooperative Wildlife Research Unit, U.S. Fish and Wildlife Service, Colorado State University, Fort Collins.

SAMPLE PATREC PROGRAM OUTPUT FOR MULE DEER

Draft Habitat Assessment

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Probability of high density potential = .5454

Probability of low density potential = .4546


Expected density potential = 48.2 per sq mi
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SAMPLE MANALT PROGRAM OUTPUT FOR MULE DEER

Cost Effectiveness Summary

Strategy - Range Fert/Mtsh

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1.  Dev + O/M Costs = $33592.00
2.  Discounted Dev + O/M Costs = $31611.48
3.  Total Goal Units = 403
4.  Cost/Unit (Item 1/Item 3) = $83.40
5.  Discounted Cost/Unit (Item 2/Item 3) =
       $78.48
6.  Probability of Success = 90%
7.  Efficiency Index (Item 6/Item 4) = 1.0792
8.  Efficiency Index (Discounted) (Item 6/
       Item 5) = 1.1468
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Impacts of Coal-Fired Power Plants on Fish, Wildlife, and Their Habitats[1]

R. Kent Schreiber[2]

Abstract.--Coal-fired power plants produce airborne combustion by-products, liquid effluents, and solid wastes (ash, FGD sludge) which are potentially harmful to fish and wildlife resources. A technical report and field manual were developed to provide guidance for analysis, evaluation and mitigation of identified ecological impacts.

INTRODUCTION

To meet the Nation's current and projected requirements for electrical energy, utilities are placing increased emphasis on coal combustion as a means of generating power. Coal presently accounts for about 40% (approx. 180,000 megawatts) of the electric generating capacity in the United States. To decrease our dependency on oil and to meet anticipated electrical energy consumption, the President has recommended an 80% increase in coal use. As with all technologies, there are environmental costs associated with the production of power from coal combustion. Although some current legislation, such as the Clean Air Act and its Amendments, provide standards which restrict the impacts to human health and welfare, interpretation of these standards and regulations in terms of fish and wildlife resources has been limited (e.g., Avery and Schreiber, 1979). There has existed no convenient and authoritative document for assisting biologists in generally identifying, evaluating, and mitigating ecological problems resulting from the use of coal in generating electricity.

OBJECTIVES

To carry out their responsibilities for the maintenance and enhancement of the environmental quality of the nation's fish and wildlife resources, biologists of the Fish and Wildlife Service (FWS), other federal and state agencies, utilities and industry must have adequate and factual information on potential ecological impacts resulting from coal combustion. In the fall of 1977, the National Power Plant Team, Office of Biological Services, initiated a Cooperative Agreement with the Department of Energy to have Argonne National Laboratory prepare several documents on the impacts of coal-fired power plants on fish, wildlife, and their habitats. The objectives of this study were threefold: 1) to synthesize and assess the existing information regarding the ecological effects from operating coal-fired power plants and from conversion of oil- and gas-fired electric generating stations to coal, 2) to identify the topical areas in which there was not yet sufficient information and data to make informed decisions regarding the protection of fish and wildlife resources, and 3) to prepare this material in formats that facilitate its best use by field biologists and decision-makers.

ISSUES

Coal-fired power plants range in size from less than 10 to over 2000 megawatts electric (MWe) and may permanently disturb a land area as large as 283 hectares (700 acres), excluding any cooling lake. Generally the adverse effects of these plants that are of most concern to biologists arise from one or both of the following:

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[1] Poster session presented at the National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

[2] Project Officer, Terrestrial Ecologist, National Power Plant Team, Fish and Wildlife Service, 2929 Plymouth Road, Ann Arbor, MI 48105.

-Elimination or physical disturbance of terrestrial and/or aquatic habitats;

-Additions to air, water, and soil of substances that have the potential for acute or sublethal effects on biota.

Environmental Impacts

Coal Slurry Pipelines

Pulverized coal may be mixed with water and transported through a pipeline system that includes the slurry preparation plant; the pipeline, associated pumping stations, water and slurry storage ponds; and the slurry dewatering plant. Impacts from this process include disturbance and removal of wildlife habitat for rights-of-way and for pumping stations and storage ponds, consumptive use of water, and the accidental discharge of slurry into local waterways.

Coal Cleaning and Storage

Coal cleaning (beneficiation), which reduces the sulfur and unwanted noncombustible materials, has as its primary source of impact the problems of coal refuse disposal. In addition to land use and dust, the seepage and runoff from refuse slurry ponds and storage piles can contribute acidic substances, solids, and trace elements to surface waters. Because of the chemical nature of many of the refuse wastes, the reclamation of inactive disposal sites may present additional ecological problems.

Limestone Storage

Lime and limestone are raw materials required for various methods of flue-gas desulfurization (FGD). Stockpiling this material preempts wildlife habitat and alkaline runoff can increase sedimentation, turbidity, and calcium in affected aquatic systems. Noise associated with limestone preparation and coal cleaning can also disturb wildlife near the site.

Air Emissions

Coal combustion produces airborne byproducts including SO_x, NO_x, particulates and various other gases and trace elements, depending on the coal composition. Additions of these materials to the air, soil, water, and vegetation can cause both direct and indirect impacts to the biota. Acid precipitation, heavy metals, and radioactive emissions all have the potential for toxic impacts to ecosystems.

Solid Wastes and Liquid Effluents

Burning coal and pollution-abatement processes generate solid wastes (slag, bottom ash, fly ash, FGD sludge) which are mixed with water and discharged to onsite disposal basins. These effluents may contain significant amounts of trace elements and particulates, or have extreme pH, thus presenting potential hazards to aquatic habitats and their biota through seepage, runoff, and overflow. Disposal sites preempt land and there may be toxification of water birds attracted to these waste ponds.

Mitigative Measures

Detailed information on these and other identified impacts, and approaches for their evaluation and possible mitigation are provided in two documents, a technical report (U.S. Fish and Wildlife Service, 1978a) and biologist's manual (U.S. Fish and Wildlife Service, 1978b) on the impacts of coal-fired power plants on fish, wildlife, and their habitats. The Report includes technical descriptions of impacts, extensive literature citations and potential mitigative measures, including the use of pollution abatement devices, erosion control, recycling of wastewater, proper siting and lining of disposal ponds, and reclamation of disposal sites. The Manual summarizes the impacts and mitigative measures and provides guidance for the collection and evaluation of the requisite information for impact assessment.

LITERATURE CITATIONS

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U.S. Fish and Wildlife Service. 1978b. A Biologist's Manual for the Evaluation of Impacts of Coal-fired Power Plants on Fish, Wildlife, and their Habitats. Office of Biological Services. FWS/OBS-78/75. U.S. Fish and Wildlife Service, Washington, D.C. 206 pp.

An Industry Information Resource to Catalog Power Plant Cooling System Impacts and Mitigation Measures Affecting Aquatic and Terrestrial Ecosystems[1]

Elizabeth H. Hannon Lois J. D'Angelo Sylvia Talmage[2]

A clearinghouse of power plant cooling system effects information, sponsored by the Electric Power Research Institue (EPRI), provides response and referral services to industry, government, and others, including literature searches of the Cooling System Effects Data Base, photocopies of documents, bibliographies, and critical reviews of the information.

INTRODUCTION

In 1972, Congress passed the Federal Water Pollution Control Act Amendments, the goal of which was to eliminate the discharge of pollutants, including heat, into navigable waters by 1985, with an interim goal of achieving water quality to provide for the protection and propagation of fish, shellfish, and wildlife. The Act had a profound impact on the electric power industry, since the majority of operating steam electric plants utilized once through cooling systems with thermal discharges into the various waterways.

In response to the Act, and particularly Sections 316(a) and (b), the electric utilities initiated numerous monitoring studies of the relationships between power plant cooling systems and resident biotic populations and water quality. These Section 316 "demonstrations" studied the existing water body in relation to the plant's cooling system, analyzed the size of the thermal plume, and measured the effects of entrainment and impingement on various representative important species (RIS) at each site. Voluminous reports, rivaling, in size, environmental reports (ERs) and impact statements (EISs), were prepared and submitted to regional U.S. Environmental Protection Agency (EPA) offices and state water quality agencies, detailing the results of these studies.

As with the case of the National Environmental Policy Act (NEPA), one of the by-products of the legislation has been the creation of a new primary source of literature, little of which has reached the scientific community through such standard channels as conferences, professional journals, or university reports. This literature, which represents in excess of a billion dollars spent by industry and government, has remained relatively inaccessible in state and Federal Government offices.

In 1975, some 30 scientists and engineers from academia, government and industry defined eleven high priority industry needs related to the assessment of cooling system effects on water quality and aquatic biota at a workshop sponsored by the Electric Power Research Institute (EPRI). One of these research needs included the creation of an industry information clearinghouse project to 1) build a data base of the original utility 316 literature as well as the published literature from the scientific community pertaining to cooling system impacts, 2) provide a central depository for utility reports and studies on aquatic ecosystems, 3) provide response and referral support services to industry and government to access the information collection, and 4) synthesize and disseminate new information by publishing bibliographies and critical reviews. As a result, two separate but complementary contracts were issued to the Atomic Industrial Forum's (AIF) INFORUM project in Washington, D.C. and the Ecological Sciences Information Center (ESIC), which is part of the Information Center Complex at Oak Ridge National Laboratory (ORNL), Oak Ridge, TN.

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[1] Paper presented at the Mitigation Symposium, Colorado State University, Fort Collins, CO, July 17-19, 1979.

[2] E.H. Hannon, Manager, INFORUM and L.J. D'Angelo, Assistant Manager, INFORUM, Atomic Industrial Forum, Inc., Washington, D.C. S. Talmage, ESIC, Oak Ridge National Laboratory, Oak Ridge, TN.

AIF's task was to identify the relevant unpublished environmental studies prepared by utilities, their consultants, and government agencies in response to regulatory requirements. Oak Ridge's effort focused on the published literature from in-house data bases, other commercial and government data bases, and information available in conference proceedings, scientific journals, government and university reports, and books.

DATA BASE

Today, the Cooling System Effects Data Base contains over 7500 references and abstracts combined from the utility studies gathered by AIF and the published literature identified by ORNL. Updates of new information are made to the file at least three or four times a year. The data base is maintained for EPRI on an international time-sharing network by AIF's INFORUM project in Washington, D.C.

The major subject areas of the data base are impingement, entrainment, thermal effects, chemical effects, atmospheric effects, and terrestrial effects. Also included are possible effects of water consumption (e.g., effects of the permanent removal of water from the system and/or fluctuation in water levels and flow). Changes in additional parameters such as pH value, oxygen concentration, light intensity, and suspended sediments are considered as well.

A user's guide to the Cooling System Effects Data Base (EPRI EA-901), published by EPRI, is available from both INFORUM and EPRI. It contains copies of the wordlist which can be used to search the data base, descriptions of major subject areas, and how to request a search.

Some recent searches have covered the following subject areas: 1) identification of power plants using specific fish protection devices, 2) the performance of fish repulsion devices to mitigate impingement at intake structures, 3) effects of cooling tower drift, salt deposition, and methods of eliminating or reducing drift, and 4) the natural mortality or die-off of gizzard shad and how to mitigate impingement of that species.

PRODUCTS AND SERVICES

In addition to literature searches on the Cooling System Effects Data Base, the project provides response and referral services including data searches on AIF's POWER Database (includes information on cooling system details), manual searches for information in specific reports, photocopy services, library usage, etc. The central depository of gray literature contributed by utilities around the country is maintained at AIF's Washington, D.C. office and is available for use by industry, government, and others. To date, some 2000 documents have been received and new reports are abstracted regularly for inclusion in the data base. A publication listing the utility reports contributed to the project (EPRI EA-872) is available from EPRI.

Three topical bibliographies generated from the Cooling System Effects Data Base on chemical effects, entrainment, and impingement were prepared by ESIC and published by EPRI in April. A fourth bibliography covering terrestrial and atmospheric effects of closed cycle cooling systems will be prepared in late summer by INFORUM.

ESIC also prepares critical reviews based on reports included in the data base. Currently, ESIC is writing a critical review on shifts in fish and benthic species presence or abundance in relation to power plant start-up or operation. The review is based on a search of the Cooling System Effects Data Base and relates thermal response information to effects observed in the field.

CONCLUSION

Since its inception, the cooling system information resource has been of assistance to hundreds of utilities, consulting firms, government agencies, and other companies who have used its response and referral capabilities to aid in answering basic ecological questions, gathering raw baseline data, planning mitigation strategies related to cooling systems, and in siting and designing new plants.

The Cooling System Effects Data Base continues to expand in size as well as scope. Future plans for the project include the publication of additional topical bibliographies and critical reviews as well as coordination of regional workshops for industry engineers and biologists to increase awareness and use of the data base and related products and services of the cooling system information project.

Impact of Winter Cloud Seeding on Winter Range of Elk [1]

James M. Sweeney[2], John R. Sweeney[3], H. W. Steinhoff[4]

Abstract.--A model was developed to estimate winter range conditions. An average 5% decrease in winter range was predicted from a 15% increase in snowpack; but may vary from 0 to 20% dependent upon how close "normal" snow depths approached critical limits. Impact of this winter range loss on elk (Cervus canadensis) is probably minimal except in normally heavy snow years.

INTRODUCTION

In 1968, the Bureau of Reclamation began work on a pilot project to develop means (thru winter cloud seeding) for increasing snowpack by about 15%, thereby enhancing spring runoff. In 1970, the Bureau awarded a contract to Colorado State University to evaluate the ecological effects of winter weather modification.

The study reported here was part of a 4-year project to determine the distribution of elk as related to snow cover on Missionary Ridge in the San Juan Mountains of southwestern Colorado. The study area was bounded on the north by Canyon Creek and on the south by Elkhorn canyon. The eastern terminus followed the crest line of Missionary Ridge, dropping in elevation from 3500m in the north to 3050m in the south. The Animas River formed the western boundary (approx. 2040m elevation).

METHODS

The study area was divided into six elevational bands (250 m wide), three aspects (N, S & W) and five cover types (meadow, shrub, aspen, conifer-cut and conifer-uncut), thereby defining 90 different habitat classes. A mosaic of habitat units was described by overlaying elevation and aspect contours on vegetation maps prepared by the Institute of Artic and Alpine Research. The area for each unit was planimetered to the nearest 0.1 hectare and assigned its elevation, aspect and cover type.

Monthly snow depths were recorded at 31 permanent snow stake sites to provide an estimate of the overall snow pattern on the study area. These sites were established in areas of representative combinations of cover type, aspect and elevation. Snow stakes were deployed in a 5-stake cross pattern, covering an area 10 m square. One leg of the cross was oriented with the contour, and the other perpendicular to the first (with the fall line).

The assumption was made that the snow depths recorded at a given snow stake site would provide an indication of snow depths for all areas on Missionary Ridge within the same elevational band, aspect and cover type. A series of 15 regression equations ($R^2 > 0.75$, $P < 0.10$) were developed from the snow stake data in order to estimate snow depths in habitat classes not directly represented by snow stake sites.

The model summarized the total area in each habitat classification, and used these areas in combinations with estimated snow depths to calculate available elk winter range on Missionary Ridge.

Winter range estimates were based on the critical depths for elk as determined by this project. Snow depths approaching 40 cm caused elk on Missionary Ridge to move to more open winter range. Areas with more than 70 cm snow were usually avoided (Sweeney 1975). Maximum elk winter range was the total of all areas with less than 70 cm snow depth; and optimum elk range was the total of all areas with less than 40 cm snow depth.

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[1] Paper presented at the Mitigation Symposium, Ft. Collins, Colorado, July 16-20, 1979.

[2] Assoc. Prof., Univ. of Ark. at Monticello, Monticello, AR.

[3] Asst. Prof., Clemson Univ., Clemson, SC.

[4] Prof., Colo. State Univ., Southwest Reg. Office, Durango, CO.

The model also applied a theoretical 15% increase in snowpack and returned the adjusted winter range values. This was accomplished by increasing the depth of snow for each habitat class by 15% of its original estimated depth. As a result, greater absolute increases were applied to the deeper snowpacks of north slopes than the shallower snowpacks of south slopes. The increase by percentage then accounted for the natural differences in accumulation usually found between slopes with differing aspects.

RESULTS AND DISCUSSION

Snowfall for the winter seasons studied was well within the natural range of variation established in long-term winter precipitation records prior to cloud seeding. Therefore, although cloud seeding was in progress during the study period, precipitation for the winter seasons was considered "normal" for use in the winter range model.

The average effect of the 15% increase in snowpack, as predicted by the winter range model, was a 5% decrease in total winter range. The effect varied depending on how close the observed snow conditions were to the cut-off points of 40 and 70 cm prior to augmentation. In some cases the 15% increase in snowpack resulted in no loss of winter range, while at other times the addition resulted in a 20% decrease in total winter range. The greatest deviation from observed conditions occurred in intermediate snow years. In these cases, maximum winter range was decreased more by the increased snowpack than was optimum winter range.

The greatest decrease occurred at the time of heavy snow conditions. These decreases had the effect of dropping the maximum winter range available to elk down toward minimum values observed in severe winters, but for only a short time. Severinghaus (1947) and Verme and Ozoga (1971), noted that duration of severe winter conditions is a key factor in resultant ungulate mortality. Also, the total area lost from optimum winter range as a result of the 15% increase approached 5% for only short periods in intermediate snow years. The impact of a 15% increased snowpack on elk therefore is probably minimal in intermediate and light snow years.

The influx of elk into developed areas of the valley, the above normal number of elk-automobile accidents recorded by the Colorado Division of Wildlife, and the apparently high winter mortality during severe winters suggests a lack of sufficient low elevation winter range. In severe winters when the maximum winter range is already low, an additional loss of 8 to 22% of the remaining area and the transfer of as much as 60% of the remaining optimum winter range to a sub-optimum condition could result in additional ungulate mortality. The impact may be lessened to some extent if two essential guidelines for cloud seeding are followed. The guidelines would 1) not allow the seeding of a storm which forecasts indicate may be severe in nature, and 2) call for the end of cloud seeding once the snowpack is 120-130% of the 20 year mean. Snowpack on the target area had reached 140% of normal during the severe winter observed.

The foregoing has been a discussion of the effect of a 15% increase in snowpack on elk under present herd conditions. Consider for a moment the hypothetical case of an elk population at carrying capacity. If the elk herd on Missionary Ridge was brought up to and maintained at carrying capacity, any snowpack augmentation resulting in decreased winter range would in turn likely cause elk mortality.

Research has shown that elk are forced onto their winter range by snow, with snow depth being the primary weather factor determining how far elk will descend from their summer habitat (Anderson 1954, Lang 1958). The winter range model was therefore based on snow depth. It did not include compensation for the modifying effects of topography, food, cover and snowpack composition; except indirectly as these factors in turn influence snow depth.

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Effects of Snow on Browse Production by Gambel Oak [1]

John R. Sweeney[2], James M. Sweeney[3], Harold W. Steinhoff[4]

Abstract.--A 4-year study in southwestern Colorado examined the effects of snow on browse production by Gambel oak. Delays in snowmelt apparently delayed initiation of growth in Gambel oak by retarding soil warm up. However, shoot elongation was always completed well before the end of the frost free season. Production of annual browse by Gambel oak probably is most closely related to summer precipitation of the previous year.

In 1970, the Bureau of Reclamation began the Colorado River Basin Pilot Project to determine the feasibility of increasing precipitation by cloud seeding on an operational basis. The San Juan Ecology Project was concurrently initiated to determine the possible ecological ramifications of augmenting snowfall. One of the biotic components chosen for study was Gambel oak (Quercus gambellii), one of the predominant cover types and an important browse species in the target area.

METHODS

A 4-year study was conducted on Missionary Ridge in southwestern Colorado to determine the effects of snow on browse production by Gambel oak. Two stands, 1.3 and 1.6 ha in size located at the upper elevational limits of oak (approximately 2900 m), were selected for intensive study.

Snow depths were recorded at monthly intervals during the winter and at weekly intervals during the spring to detect date of final melt. Soil moisture and temperature data of the primary root zone (to 117 cm in depth) were recorded at semi-weekly intervals during the early growing season and at weekly to monthly intervals during the remainder of the year. Daily precipitation and ambient temperature were obtained from a weather station 0.5 km northwest of the study sites.

Phenology of the larger stand was recorded during each growing season. Ten to 20 buds from 5 stems at each of 10 plots were marked and the lengths of the developing leaves and twigs were recorded every 3 days from May 13 through July 18. Three methods were used to sample browse production - clip plots, measurement of current year's twig lengths, and measurement of the last 5 consecutive years' twig lengths. Current annual growth from the clip plots was dried and weighed to the nearest gram. The other two methods used length in mm, of the twigs produced each year, as an indicator of relative growth and production (Sweeney 1975). In the last method, annual growth for the last 5 years was differentiated by the terminal bud scale scars.

RESULTS AND DISCUSSION

Environmental factors which affected the production of browse in Gambel oak influenced either the date of initiation of growth or, apparently, the development of the buds but did not appear to influence the duration of elongation.

Those factors which were most closely associated with the date of initiation of growth were the date of final snowmelt and the seasonal warm-up in ambient temperatures. Seventy-five percent bud burst was recorded during the third week in May for the 2 years with early snowmelt. When the snow did not melt off until mid-May as in 1971 and 1973, initiation of growth was not recorded until June 9.

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[1] Paper presented at the Mitigation Symposium, Ft. Collins, Co., July 16-20, 1979. Study supported by Bureau of Reclamation Contract No. 14-06-D-7052 with Colorado State University. Technical Contribution no. 1714 published by permission of the Director, South Carolina Agricultural Experiment Station.

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Soil temperature appeared to be the primary mechanism through which snowmelt affected initiation of growth. A minimum period of about 5 weeks was required after snowmelt before initiation of growth in Gambel oak occurred. It took 18 to 20 days for the soil to warm up to 4°C and an additional 2 weeks elapsed before initiation of growth. This time was apparently needed for the necessary root processes to begin functioning. Snowmelt, through its affect on soil temperature, may cause a delay in bud burst but an early warm-up in soil temperatures did not appear to be the primary factor influencing early growth initiation. In 1972 and 1974 at least 11 weeks elapsed after snowmelt before initiation of growth was recorded. Bud burst of Gambel oak in the target area may not occur any earlier than the third week in May due to photoperiod requirements preventing an earlier bud burst.

A minimum period of warm air temperatures may also be required before bud burst occurs. For the 3 years such data were recorded, temperatures rose to 10 to 12°C at the time of bud burst. Also, cumulative air temperatures reached 305 and 310 degree-days prior to bud burst in 1973 and 1974 respectively even though the date of bud burst varied by 2 weeks.

Gambel oak had a short period of shoot growth of 24 to 27 days which was completed by the first week in July. Duration of shoot growth did not respond to normal current environmental fluctuations but remained consistent each year. Since neither normal fluctuations in climatic conditions nor delays in the date of growth initiation appeared to affect the duration of shoot elongation, the length of this period in Gambel oak was probably genetically controlled. However, severe climatic conditions can prematurely terminate shoot growth. Production in 1974 was abnormally low due to killing frosts early in the growing season.

The amount of annual browse produced by Gambel oak was significantly ($P<0.05$) lower in 1972 than in either 1971 or 1973. Since the period of twig elongation was the same for these 3 years the rate of shoot expansion was reduced in 1972, apparently due to a decreased supply of stored foods in the bud rather than to less favorable environmental factors extant during the time of growth. Data from this study showed no relationship between production of browse and normal current temperature or moisture conditions. However, a direct relationsh between production of browse by Gambel oak and precipitation of the preceding summer was recorded. In each year of study, the period of leaf expansion in Gambel oak exceeded the period of twig growth. Since young growing leaves do not readily export large amounts of assimilates to other plant parts (Kozlowski and Keller 1966) annual production of browse by Gambel oak probably was primarily dependent upon carbohydrate reserves stored in the buds of the previous year. Summer precipitation has been the environmental factor most often report as affecting this bud development (Zahner 1968)

Therefore, the primary factor which influences the production of browse in Gambel oak on Missionary Ridge is probably summer precipitati An increase in snowpack will have little if any direct affect on the production of browse. Snowfall, however, may indirectly influence the amount of carbohydrates stored in the buds. A delay in snowmelt may decrease the length of the complete growing season by delaying the dat of initiation of growth. The duration of shoot elongation in Gambel oak is genetically controlled and is 24 to 27 days long regardless of the timing of bud burst. Therefore, the period after shoot elongation, that is the period of b development, will be the portion of the growing season which is shortened by a delay in the timing of the bud burst. Snowfall may therefore decrease the amount of time that food supplies can be stored in the buds. However, whether or not such a reduction in time will significantly reduce the amount of food stored in the buds will in turn be dependent on the climatic conditions extant during those periods, especially summer precipitation.

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Mitigation of Impacts Affecting White-Tailed Deer at the Seven Mile Project, British Columbia[1]

GUY P. WOODS[2]

ROBERT M. BRADLEY[3]

Abstract.--1.8 Million dollars was awarded to the British Columbia Fish and Wildlife Branch as compensation for the loss of deer winter range to a hydro-electric project. A permanent interest-bearing fund has been established. Deer management plans have been developed. Mitigation was emphasized in early planning, while compensation funds ensure land purchase, and the implementation, operation and maintenance of management plans.

INTRODUCTION

The Seven Mile Project is located on the Pend d'Oreille River, a tributary of the Columbia River, in southeastern British Columbia. The project features a 65 m concrete gravity dam creating a head pond that will flood 13 km upstream to the Canada/USA Boundary. The topography is steep and mountainous resulting in a total flooded area of 212 hectares. Access construction and work areas have eliminated a further 90 hectares, resulting in the loss of more than 10% of the winter habitat of 1300 white-tailed deer (Odocoileus virginianus). Construction work commenced in 1975 and the first three generating units are scheduled for service in 1980.

HISTORY

In the spring of 1974 B.C. Hydro and Power Authority (BCHPA) applied to the Comptroller of Water Rights, the authorizing agent for water diversion and storage in the Province of British Columbia, for a water licence permitting the construction of the Seven Mile Project. In recognition of the potential environmental problems associated with the project BCHPA had carried out an environmental impact study emphasizing wildlife, fish and recreation in 1973-1974. In July 1974 a water licence hearing was held.

Central in the concerns of biologists and naturalists representing the intervenors and B.C. Hydro at the hearing were impacts of the project on critical white-tailed deer winter range. Fishery concerns were minimal and were judged by both parties not to be a problem. Road access to the project was a controversial issue at the hearing. Three alternative routes which were considered consisted of a road parallel to the Pend d'Oreille River on the north side of the river, a road parallel to the Pend d'Oreille on the south side, and one approaching from the north via Nine Mile Creek (fig. 1). It was concluded during the hearing that the "South Side" route was best environmentally, the "North Side" was best financially while the Nine Mile route was judged unacceptable from a social point of view. A Conditional Water Licence was issued to BCHPA authorizing diversion and use of water subject to, among other conditions, construction of either a north or south side road and funding of a wildlife habitat protection programme.

After B.C. Hydro re-evaluated access alternatives a second hearing was held before the Comptroller of Water Rights in April 1975, to decide the access route question. The dam per se was not an issue at this hearing, but factors such as deer habitat loss, direct deer mortality, construction costs, human safety and disturbance to deer were considered in relation

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[1] Paper presented at the Mitigation Symposium, Fort Collins, Colorado, July 16-20, 1979.

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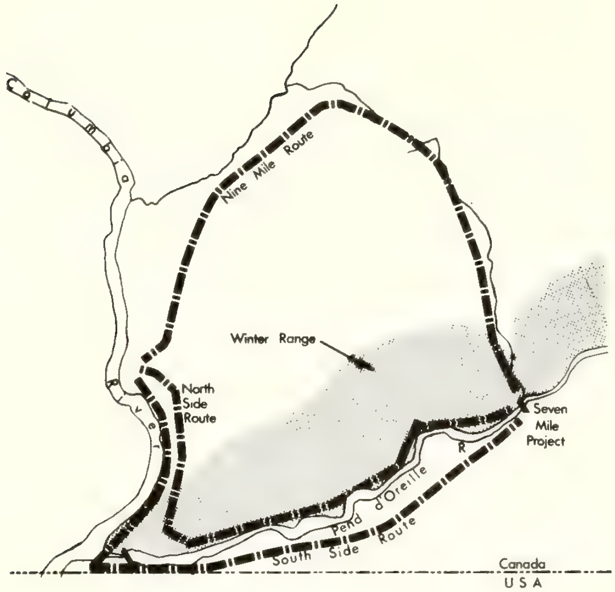

Figure 1.--Access routes from the concrete gravel pit to the Seven Mile Project.

to the two remaining access alternatives. The Comptroller's ruling, May 1975, supported BCHA's application for a route on the north side of the valley immediately adjacent to the existing Waneta Reservoir on the Pend d'Oreille River. His decision also directed:

> "...... that the licencee shall make available to the Department of Recreation and Conservation a total of one million eight hundred thousand dollars (1,800,000) in accordance with budgets submitted annually by that Department for planning and implementing a fish and wildlife habitat management program for the Pend d'Oreille Valley, having due regard for the principles of integrated resource management."

Following this directive, appeals to a Cabinet committee were launched by the Trail Wildlife Association and the Fish and Wildlife Branch of the then Department of Recreation and Conservation. After evaluating all the evidence available the Cabinet committee disallowed the appeals and referred "the question of compensation for the loss of use of the natural amenities of the fish and wildlife habitat" to the Environment and Land Use (ELUC) Secretariat, a government body responsible to a Resource Cabinet Ministers' committee, and entrusted with investigative responsibility.

The final decision on compensation was handed down by the ELUC Secretariat in September 1977 and upheld the previous compensation award. The money was established as a permanent investment fund with B.C. Hydro paying an interest rate tied to their yearly adjusted borrowing rate. Unused interest during any given year is maintained in the fund and is added to the capital. Money spent above the yearly interest yield, such as major land purchases, reduces the capital. The arrangement allows the Fish and Wildlife Branch to own and manage land on a long term basis, to put into effect an intensive habitat management plan, to operate the plan, to conduct required research, and to monitor the results of management efforts without affecting normal Branch budgeting.

MITIGATIVE EFFORTS

"Mitigation" refers to any action taken during planning, construction or operation phases which reduces the severity of an impact. Mitigation efforts at Seven Mile include relocation of camp, office, and work areas, revegetation of exposed areas, and delaying reservoir clearing on winter range. Increasing the awareness of designers, construction supervisors, and field personnel sensitive to environmental concerns is of immeasurable value in achieving mitigation benefits. The presence of an on-site biologist provides indirect benefits by encouraging and nurturing conservation attitudes in the construction force and direct benefits by rapid ecological evaluation of alternatives.

COMPENSATIVE EFFORTS

"Compensation" implies that irreversible damage to habitat has occurred, and that action is being taken to replace some or all of the losses. The impacts imposed on white-tailed deer were recognized by the Water Comptroller's provision of a $1.8 million compensation fund. The Fish and Wildlife Branch has used this fund to purchase key parcels of land, to obtain management options for other parcels of land, to complete research on habitat requirements of white-tailed deer, and to develop and implement a wildlife management programme. To date a total of 560 hectares of land has been purchase and options secured on an additional 405 hectares.

Research activities designed to identify the local habitat requirements of white-tailed deer were initiated in 1974 to build the basis for an intensive wildlife management programme (Woods, 1979a). Four major research objectives were identified:

(a) To establish seasonal movements and habitat selection patterns of the Pend d'Oreille white-tailed deer. Habitat selection during winter was considered to be the most important part of this programme as existing winter range is limited relative to the area available for summer use.

(b) To develop an understanding of the inter-relationship of climate, topography, and vegetation in the winter range area so that enhancement activities could be identified.

(c) To quantify factors affecting carrying capacity of the winter range.

(d) To identify the size of the deer population and establish methods of monitoring changes in this population in order to evaluate the effectiveness of habitat enhancement programmes.

Techniques used to meet these objectives, included ground observations, radio telemetry, track counts, pellet group transects, vegetation mapping, climate and snow depth monitoring, and food habitat studies. Radio telemetry techniques were important in overcoming difficult terrain and provided valuable data on winter habitat selection (Woods, 1979b) and yearly movement patterns of white-tailed deer in this area (Woods and Woods, 1979).

A five year Wildlife Management Plan identifying broad management intentions was prepared as a condition of the compensation award (Dick et al, (ms) 1977). Detailed area and site plans are being prepared utilizing soils, landform, vegetation, and deer habitat selection data. The Resource Analysis Branch, Ministry of Environment, recently mapped current vegetation, soils, and slope in the valley at a scale of 1:20,000 to provide a basic inventory and a basis for detailed management prescriptions (Vold et al, 1979). These prescriptions will be implemented in an attempt to maintain deer numbers in the Pend d'Oreille Valley.

The loss of critical deer winter range caused by reservoir and access requirements associated with the Seven Mile Project may be partially offset by intensive management of remaining habitats. Costs associated with maintaining the white-tailed deer population at levels comparable to those present prior to dam construction will be high. Some methods planned to achieve intensive management are still untested in Canada.

SUMMARY

Experience on the Seven Mile Project has demonstrated the need for emphasis on mitigation efforts during the early planning stage. Once construction begins the effectiveness of mitigation decreases. Conflicts arise, situations change, and new deadlines cause problems. In addition the costs of responsive mitigation are higher than those of planned mitigation, ie. action is better than reaction.

The $1.8 million compensation fund ensures that adequate money is available for planning, implementation, and monitoring a deer management programme in the Pend d'Oreille Valley. Awarding of the fund is unique in British Columbia and will help to reduce the long term impact of habitat losses caused by the Seven Mile Project. It must be noted, however, that despite the fund, construction of the project access road on the south side as a mitigative effort would have been preferred as it would have maintained the high deer capability land base for management. Monetary compensation and the resulting intensive management involves attempting to achieve maximum productivity from the remaining land base. This optimization for deer may not always be possible due to conflicts with other resource values and uses, and due to unanticipated changes in government policy.

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Mule Deer Losses — Mohawk Canal, Arizona: A Problem Identified - A Solution Sought[1]

Herbert R. Guenther[2], F. Phillip Sharpe[3], and Paul Strauss[4]

Abstract -- Mule deer losses in the Mohawk Canal has become an acute problem. Modification of existing escape structures and design of ramp-type escape structures is being accomplished to minimize mortality. The effectiveness of these escape structures will be evaluated using sophisticated optical monitoring systems. Different configurations of escape structures, deflection devices, and other passive measures will be tested.

AREA DESCRIPTION

The Mohawk Canal is a lined irrigation canal serving the eastern portion of Wellton-Mohawk Valley, Yuma County, Arizona. A portion of this canal has a history of high, desert mule deer losses and was therefore chosen by the Bureau of Reclamation for a study on large animal escape structures.

The portion of the Mohawk Canal chosen for the study is a 6.2 mile section on the north side of the valley. This section runs from east to west, with desert to the north and farmland to the south. It has three drop structures and three check gates, about a mile apart. During the 1960's, the Wellton-Mohawk Irrigation and Drainage District (WMIDD) installed deer escape structures just above each gate and drop structure consisting of 16 inch by 10 foot steps in the side of the canal. Some escape structures have two steps and others three steps.

The south side of the canal is agricultural land on which alfalfa, cotton, pecans, and wheat are primary crops. As the growing season is year round, the Mohawk Canal always contains water.

The desert side of the canal is riddled with washes that begin in the Castle Dome and Kofa Mountains and flow south to intercept the canal alinement. The dominant vegetation along the washes consists of mesquite, palo verde, and smoke tree.

The area's climate is one of hot summers and warm winters. Summer temperatures frequently exceed 110 degrees fahrenheit while winter daytime temperatures usually range from 65-75 degrees fahrenheit. Annual rainfall averages less than 4 inches, which mainly occurs in two seasons, July through September, and December through March.

THE PROBLEM

Mule deer from the surrounding mountains travel the desert washes to water in the Mohawk Canal and/or feed in the agricultural fields. Although this movement occurs year-round, it is most prevalent during hot, dry spells (usually May, June, and July). In attempting to cross or water, the deer jump, slide, or walk into the canal. If the water in the canal is near the top, the deer usually manage to escape on their own. However, if the freeboard between the water surface and the top of the canal exceeds 12 inches, the mule deer are unable to escape without assistance.

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Once in the canal, reactions vary with the individual deer. Generally they will make one or two attempts to escape near the point of entry. Failing this, they tend to swim against the current, attempting to escape where bushes and grass overhang the canal. Tiring rapidly but still swimming, they allow the current to carry them while pawing at the lining on both sides of the canal trying to escape. Upon reaching a drop structure they either drown or are forced through and killed. Those that come upon a check structure thrash around until exhaustion causes drowning or, in the case of large bucks, the overhang of the structure pins their antlers down, forcing their heads under water. A fortunate few accidentally find the existing escape structures and escape from the canal unassisted. Occasionally, one will get out on a human escape ladder. Some are rescued by ditchriders or Arizona Game and Fish personnel, and others are killed by poachers.

The existing step-type escape structures are almost totally ineffective because they are submerged and the deer can't see them from the water surface.

During 1978, the Mohawk Canal accounted for the death of 33 mule deer. Losses are due to direct causes such as drowning and fatal injuries suffered going through drop structures. Other losses are due to indirect causes such as injuries sustained in escape attempts, shock, pneumonia, and the death of orphaned fawns. Escape attempts commonly result in skinned knees and hocks, broken legs and dislocated stifles. Deer with jaws broken by going through drop structures are occasionally found. The exact number of indirect losses will never be known because some deer escape and die later in the desert from injuries, shock, pneumonia and increased susceptibility to predation caused by exhaustion.

The mule deer population in the Wellton-Mohawk area appears to fawn later than do most other populations in Arizona. The majority of the fawns are born toward the end of the summer rainy season (August or September). Lactation appears to require more water, and should a dry spell occur in September or,October, large numbers of does with young fawns appear along the canal alinement. Often the does enter the canal and are followed by their fawns. The fawns that remain behind generally die from starvation or predation. Fawns escape easier than adults, thereby increasing the number of orphaned fawns. Many orphans are captured by ditchriders or Arizona Game and Fish personnel who attempt to raise them in captivity. However, the mortality rate of orphaned fawns exceeds 80 percent.

Sixty-nine mule deer were rescued from the Mohawk canal in 1978 by dedicated WMIDD ditchriders, Arizona Game and Fish Department personnel, and private citizens. The animals were roped and dragged to safety, which was time-consuming and often hazardous. The larger deer, especially large bucks, are very difficult to handle by solitary patrollers. If the person on patrol cannot handle an animal, he calls for assistance on the radio. If that assistance is not immediately available, the deer usually drowns. Once an animal is pulled onto the bank it is marked for future identification. Then the difficulty is in releasing the animal while retaining possession of the rope.

STUDY AND SOLUTION

We at Reclamation realize that it is impossible to keep all large animals, especially mule deer, from entering an open concrete-lined conveyance channel. We also recognize the trend to line canals and the proposed construction of hundreds of miles of new concrete-lined canals in the western United States. In some areas, the small number of animal losses does not warrant spending large sums of money for escape structures and associated hardware. However, in most areas the problem of animal losses in canals is acute, or has the potential of becoming so, and the construction of effective escape structures is essential.

In many instances the escape structures can be designed with other features, such as a ramp allowing maintenance equipment access to the canal prism. The purpose of this study is to modify existing escape structures to minimize losses and to develop new effective escape structures that can be used in most concrete-lined conveyance systems. The goal of the program is to minimize the loss of large mammals in lined canal systems.

To accomplish this purpose, the study has four specific objectives:

1) To develop effective large animal escape structures for use in concrete-lined canals.

2) To minimize the deer loss problem on the Mohawk Canal, Wellton-Mohawk Valley, Arizona.

3) To test the feasibility of constructing oases-type watering structures to reduce the number of animals entering lined canals.

4) To determine the potential for integrating human escape devices with animal escape devices.

For any escape structure to be effective, the animal must be able to locate it. In an effort to aid the animal in locating the structure we have developed deflection hardware prototypes consisting of floating deflector booms and suspended flasher cables. These deflectors are installed at a 45 degree angle toward the escape structure. The deflector booms act as both a visual and physical barrier intended to direct the animal to the escape structure. The flasher cables act as a visual device to accomplish the same purpose.

We also are attempting to develop deflection hardware that requires minimal maintenance. In order to test both the effectiveness and maintenance requirements of the deflection hardware, we have installed various types and configurations of devices on six existing step-type escape structures located along the Mohawk Canal. There are three basic configurations currently being tested: deflector booms only; suspended flashers only; and combined booms and flashers. All of the devices are detachable to allow for canal maintenance activities.

To evaluate the effectiveness of the deflection hardware, our instrumentation laboratory at the Denver Engineering and Research Center is developing optical monitoring systems. These systems will consist of both infrared and conventional cameras controlled by a micro-processor which can be activated by a trip device located upstream from the deflection devices. The infrared cameras have sequenced infrared strobes which cannot be detected by the animal being photographed. The micro-processor is programmable to operate either system, infrared or conventional, in any sequence. We intend to use infrared cameras with strobes when there is insufficient light for conventional photography and both cameras without strobes when the light is adequate. Only by analyzing the behavior of the animals responding to the deflection devices and escape structures can we evaluate their effectiveness and devise modifications.

We soon plan to construct at least four ramp-type escape structures along the Mohawk Canal with associated deflection hardware and monitoring systems. Of major importance in locating and spacing the new structures is finding where deer most frequently attempt to cross or water from the canal alinement. Therefore, we drag the maintenance road on the desert side of the canal bi-weekly, and monitor it for animal tracks. In addition, when an animal has been in the canal, we survey the area to find where it entered.

The areas of most frequent ingress and egress will be used to place oases-type watering devices. These devices will involve a groundwater well, windmill, storage reservoir, lined pond and overflow apron. They will provide water and food for wildlife away from the canal alinement. They will become habitual watering and feeding areas for large animals, and by reducing the animals' range, will limit their chances of entering the canal. These will also be evaluated using the optical monitoring systems.

All deer currently being assisted from the canal are being tagged and collared for future identification. This work is being accomplished by personnel of the Wellton-Mohawk Irrigation and Drainage District and Arizona Game and Fish Department. This allows us to identify repeat animals and will eventually give an indication of indirect mortality. In addition, we plan to conduct aerial surveys during the fall and winter months to determine the size of area and populations being affected by the canal. This may lead to the location of additional watering facilities in areas far removed from the canal and contribute to a reduced mortality.

This study is but one of several currently being conducted by Reclamation in Western United States. They are being accomplished under the guidance and coordination efforts of the Commissioner of Reclamation's Committee for Wild and Domestic Mammal Control in Concrete Lined Canals.

A Machine for Mitigation of Salmonid Spawning Habitat From Silting [1]

Walter C. Mih[2] and Gary C. Bailey[3]

Abstract--A machine developed to remove silt and sediments from spawning gravels utilizes high-velocity hydraulic jets, a suction system and separation system. The unit travels in the streams during the cleaning operation, and sprays the removed silt on the stream banks above the high water level.

INTRODUCTION

Pacific Salmon are anadromous fish that mature in the sea and use inland streams for spawning, incubation, and rearing purposes. Most spawning occurs where the streambed has a certain gravel size and compactness. During the more than 90-day period between spawning and fry emergency, the streambed must have an adequate intragravel water flow to supply oxygen to the eggs and emerging fry. The presence of large amounts of fine sediments in the spawning gravel causes a high mortality rate by reducing the intragravel water flow.

The size of detrimentally fine material is generally considered to be 3 mm and smaller. Andrew (1974) found that one percent increase in material less than 3 mm resulted in a one percent decrease in fry survival. Wilson and Sheridan (1974) estimated the normal egg-to-fry survival averages 10 percent in silted beds, while the survival rate increases to at least 40 percent after gravel cleaning, a four-fold increase.

ALTERNATIVES

Several alternatives are available to reduce detrimental fine materials in natural spawning beds:

1. Reduce the source of fine material upstream from the spawning bed. - If there are not sources of fine material, natural stream flow will clean the bed over a period of time. However, sources of fine sediment increase as the population increases with its accompanying construction and logging activities. Basin-wide soil conservation measures will be costly and difficult to enforce. Consequently, artificial means should be employed to remove fines, especially in selected spawning locations.
2. Replacement of the spawning bed with new gravel. - Suitable gravel can be brought in from other locations to be placed on the streambed, or excavation of the existing bed to screen out fine material (Gerke 1973; International Pacific Salmon Fisheries Commission 1972; Wilson 1975). This method can be used for artificial spawning beds; however, it is costly for natural spawning reaches.
3. Mechanical disturbance to stir up fine material into suspension in the stream flow. - Tractors with rakes or blades can be used to stir the bed and cause fine materials to be carried away in the flowing streams (Gerke 1973; Wilson 1975). Problems occur when the stream velocity is too low to transport fines away, or when the fine material settles downstream covering any spawning areas below the disturbance. This method has been tried with some degree of success.
4. Hydraulic disturbance by sluice gate action--baffle gate. - The Bureau of Reclamation's Tehama-Colusa Canal in the California Central Valley Project is the first known dual-purpose canal being both as a salmon

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spawning ground and as channel to supply water for irrigation (Carlson 1967). Large amounts of clay and silt settle into the 2.5-foot thick layer of gravel placed in the bottom of the concrete-lined canal for spawning. An adjustable baffle gate, mounted on a carriage spanning the 140-foot wide canal, can be lowered into the water. The increased velocity of water beneath the gate scours the gravel bed, and flushes out the fine sediment which is carried downstream. This method would be difficult to use in natural streams because of the irregular shape of streambeds as well as the large force required to hold the gate in place.

5. Hydraulic flushing and suction system.- High pressure hydraulic jets are used to dislodge sediments. The silt laden water is collected by a suction system and discharged to the stream bank. This method was used by the U.S. Forest Service (1964) in a machine called the "Riffle Sifter." This design was unsuccessful mainly because the jet pipes and nozzle were designed to run 12" into the gravel which resulted in frequent breakage.

It appears, however, that hydraulic flushing with high velocity jets has a potential of economically cleaning stream gravels if the jets could be placed above the stream gravels and still effectively remove the fine material.

We began laboratory testing in 1977 for the design of a system using high velocity jets above the gravel and a suction hood to collect the silt and consequently reduce the amount of water transported to the stream bank or disposal site.

LABORATORY TESTS

Jet flushing tests were performed on an average spawning gravel placed in a 4 by 20 foot transparent flume. The graded gravel has a maximum size of three inches. Fine white sand of 0.005 inch diameter was mixed with the gravel to simulate the fine material found in spawning gravel. Extensive tests were made with jets of different sizes, which were set at various jetting velocities, angle of impingement, elevations above the gravel bed and forward speed of the nozzles (machine speed). The ranges of the variables tested were:

Jet diameter	0.5, 1.0, 1.5 inches
Jet velocity	35, 50, 70 ft. per second
Angle of impingment	45°, 60°, 90° from the horizontal
Nozzle elevation from	from 0 to 20 inches above gravel surface
Nozzle forward speed	0, 0.2, 0.5, 1, 2 ft. per second

Results of the test program indicate that the high velocity hydraulic jets are an efficient means for the removal of fine material from spawning gravel. For instance, a stationary one inch diameter jet at 70 feet per second jetting velocity can remove fine materials from the gravel to a depth of 18 inches deep. Various configurations of hoods placed around the jet for confinement and removal of turbid water caused by jetting action were also tested.

DESIGN OF THE MACHINE

The first prototype gravel cleaning machine is built with small spawning streams in mind where the machine will be tested initially. Based on the results of laboratory tests and practical considerations, the design criteria are as follows:

(1) Jet diameter-All three jet sizes tested (0.5, 1.0, 1.5 inch) could be used for the cleaning operation. The smaller jet size would require higher jet velocity to have the same cleaned depth as the larger jet. A jet diameter of 3/4 inch was selected for a more reasonable flow rate on the machine.

(2) Jet velocity-For 3/4 inch diameter jet, the jet velocity should be 90 feet per second. The cleaned depth is 14 inches and the cleaned width is 28 inches.

(3) Angle of impingement - The difference in cleaned depth among jet angles of 45°, 60° and 90° is not large. The jet angle of 90° will be used.

(4) Nozzle speed (machine speed) - The speed of the machine should be less than 0.5 feet per second for deep cleaning.

The machine (fig. 1, fig. 2) consists of three pumps and a small diesel engine mounted on a 8' wide by 10' long trailer. The trailer will be towed by a 8' wide log skidder, during the cleaning operation. Three separate cleaning hoods, each two feet wide, are placed side by side. On top of each hood, there are two 3/4' diameter jet nozzles and two 3-inch diameter suction ports. The spacing between the nozzles is 12 inches and each nozzle is located 8 inches in front of a suction port. There are a total of six 3/4 inch diameter nozzles on the three cleaning hoods to provide a cleaning width of six feet. The arm of each hood is pinned to the rear of the trailer permitting independent movement of each hood over uneven streambeds. The hoods are mounted on skids six inches above the gravel. Flexible hoses connect the cleaning hood to the pumping equipment on the trailer.

The impinging water jets flush out the silt in the gravel and produce a mixture of sand and water near the streambed surface. The

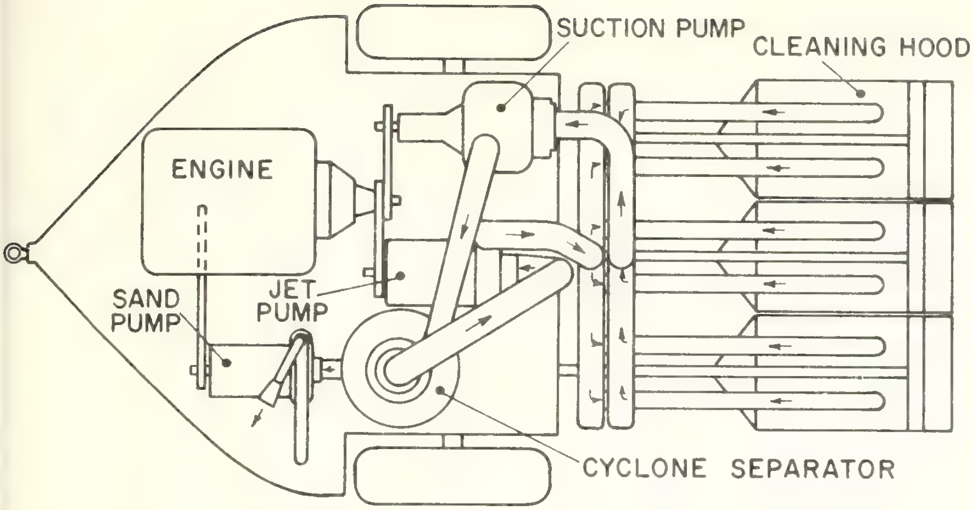

Fig. 1.--Top view of gravel cleaner. Arrows indicate direction of flow.

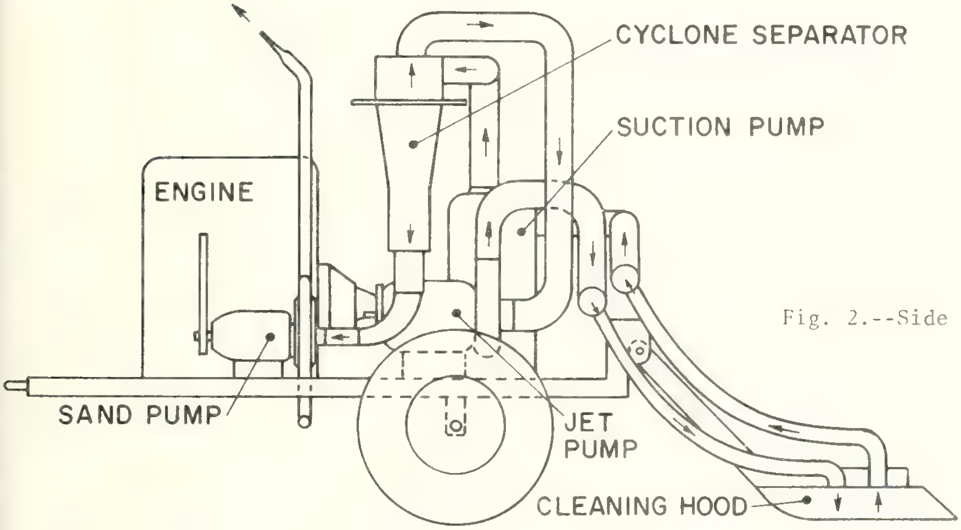

Fig. 2.--Side view of gravel cleaner.

three inch diameter suction ports serve as inlets for the sand-water mixture into the cleaning system. Flexible hoses carry the mixture to a six inch self-priming centrifugal pump. The discharge of the pump goes to a cyclone separator. The fluid mixture enters the cone tangentially and the high centrifugal force within the separator causes the heavier sand and silt to move to the outer wall while cleaner water stays in the middle. The concentrated silt passes out the apex of the cone to a small sand pump. The silt is pumped through a special nozzle to spray it on the stream banks above the high water level or through a long fire hose to a suitable dump site. The cleaner water at the middle of cyclone separator will be boosted to a high pressure at the jet nozzles for 90 feet per second jet velocity for the flushing action. Approximately 85% of the water is recycled in the machine and about 15% is used for the silt slurry discharge.

The machine has been designed and constructed. Field tests in the spawning streams of the Puget Sound area are being conducted.

ACKNOWLEDGEMENT

Funding support for the development of the machine is provided by: Washington State Department of Fisheries; National Marine Fisheries Service of the National Oceanic and Atmospheric Administration; and Washington Water Research Center.

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Ecological Monitoring of Mitigation Procedures Used for Acid Heavy Metal Leachates in Southeastern Tennessee[1]

John A. Arway[2], Wesley F. Porak[3], and Eric L. Morgan[4]

Abstract.--Mitigation of acid drainage from highway embankments in the Cherokee National Forest was undertaken by the Federal Highway Administration in 1978. The purpose of this study is to evaluate the suitability of mitigated streams for supporting fish life. Fish accomodation in the lower reaches of affected streams occurred during temporary sodium hydroxide treatments. However, three months following completion of permanent soil covering of road embankments, water quality is inadequate to support fish life.

INTRODUCTION

Construction of a highway between Tellico Plains, Tennessee and Robbinsville, North Carolina began in 1965. More than a decade later in 1977, acid drainage from recently completed portions of the Tellico-Robbinsville Highway adversely altered the water quality and the abundance of aquatic life in the adjoining North River and Citico Creek drainages (Wilson, per. comm.).[5] Geological rock formations known locally as the Anakeesta formation, a sulfide-rich pyritic and pyrrhotitic strata are the source of acid drainage from road embankments (King et. al. 1968). McNabb Creek, Hemlock Creek, and Grassy Branch (Figure 1), with headwaters adjacent to the highway, exhibited depressed pH values, increased concentrations of sulfates, heavy metals and acidity (Blackburn and Bergendahl 1977).

The scenic highway crosses the Cherokee National Forest in southeastern Tennessee situated in the Unicoi Series of the southern Appalachian Mountains. Topographically, the area has rather narrow, steep-sided ridges with elevations ranging to 1668 m (5472 ft). Local streams are typically softwater streams and are slightly acidic in nature. The North River and Citico Creek drainages lie within the Tellico Wildlife Management Area where an excellent trout fishery exists as both stocked and native trout streams.

Mitigation of the acid drainage problem was initiated by the Federal Highway Administration (FHWA, Region 15) in 1978. Sodium hydroxide neutralization was used as a temporary measure to treat acid leachates while surface sealing of the road embankments with soil was being employed as a more permanent corrective procedure. The objective of this on-going study is to investigate the response of fish communities in the North River and Citico Creek drainages to the mitigation strategies. In light of water quality data, information on the biological communities will be used by the FHWA to evaluate the effectiveness of the mitigation measures.

Anakeesta Leachate Mitigation Measures

As an interim mitigation measure, sodium hydroxide (NaOH) neutralization of acid receiving streams began May 1978 and extended through January 1979. A 20% solution of NaOH was gravity metered into the headwaters of Grassy Branch, Hemlock Creek, and McNabb Creek

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[1] Paper presented at the National Workshop on Mitigating Losses of Fish and Wildlife Habitats, Colorado State University, Fort Collins, Colorado, July 16-20, 1979.

[2,3,4] Environmental Biol. Research Program, Tennessee Tech. Univ., Cookeville, TN 38501.

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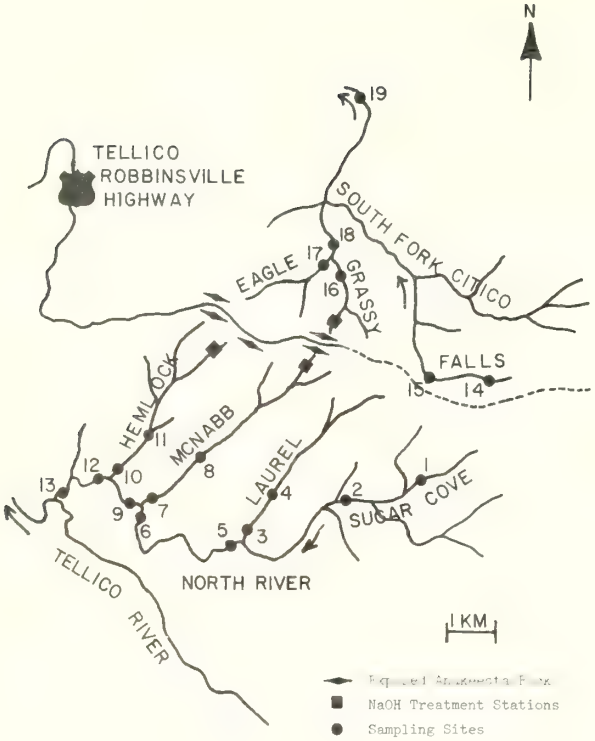

Figure 1. Map of Study Area.

(Figure 1) in an attempt to maintain a pH level of approximately 5.8 at the mouths of these streams. (Blackburn and Bergendahl 1977). This neutralization procedure also precipitated some potentially toxic heavy metal ions as insoluble metal hydroxides. Additional remedial actions taken in attempt to reduce leachate runoff included asphalt curbing, ditching, and surface drain installations. A lime slurry (approx. 60 tons/acre) was sprayed over selected embankments to prevent migration of acid salts into overlying soil layers to be installed during permanent abatement measures.

Permanent FHWA mitigation involved sealing of exposed Anakeesta material in the road embankments from surface water infiltration and oxidation-reduction mechanisms associated with pyritic material and subsequent sulfuric acid production. Following the addition of lime, a minimum of 2 feet (0.6 m) of topsoil was placed over exposed rock material and seeded with grass. A fiberglass roving layer followed by a coating of tar was then used to cover the soil to inhibit erosion. Silt barriers were also placed below soil covered embankments to reduce inherent siltation problems. Permanent surface sealing of selected embankments was completed by December 1978.

MATERIALS AND METHODS

Fish populations were sampled quarterly by electrofishing single 61 m (200 ft) stream sections at 8 sites in the Citico/North River drainages (Figure 1). Hatchery rainbow trout (*Salmo gairdneri*) placed in test baskets were used in 4-day (96 hr) in-stream bioassays conducted quarterly to evaluate the suitability of mitigated streams for sustaining fish life.

Physical/chemical water quality parameters measured monthly at 19 sites included: pH, conductance, alkalinity, acidity, hardness, temperature and selected heavy metals (Al, Fe, and Mn).

RESULTS

In 1977, prior to mitigation, the USDA Forest Service conducted preliminary fish surveys and found no fish life in McNabb Creek, Hemlock Creek, and Grassy Branch. During pre-mitigation in-stream bioassays conducted in May 1978, 100% rainbow trout mortality resulted within 24 hrs near the mouths of McNabb and Hemlock Creeks. Low pH (4.0 to 4.4) and alkalinity combined with increased acidity and heavy metal concentrations contributed to the acutely toxic conditions at these impacted sites.

Mitigated streams showed a general improvement in physical/chemical water quality during NaOH neutralization measures (Table 1). Positive trends were supported by results of in-stream bioassays conducted during August and December 1978. Rainbow trout mortalities ranged from 0 to 45% after 96 hrs exposure at mitigated sites where 100% mortalities had occurred within 24 hrs prior to mitigation. Fish population sampling substantiated these results revealing a subtle migration of rainbow trout and creek chubs (*Semotilus atromaculatus*) back into the lower reaches of McNabb and Hemlock Creeks (Table 2). Movements of fish in the Citico drainage back into study sites on Grassy Branch and Eagle below Grassy was not observed during this same period. Lack of recruitment into impacted sampling areas on Eagle and Grassy may be attributed to the distance required for fish to migrate upstream into these headwater areas in addition to the small number of fish available for recruitment. Longitudinal pH profiles taken in mitigated streams during NaOH treatments indicate pH neutralization (pH to 7.0) did not occur until approximately 2000 m downstream of metering stations. Caustic pH values as high as 13.0 occurred immediately below these treatment stations. Under these conditions, biological accomodations seen at downstream sites during NaOH treatments were not expected in the headwaters of these streams. Introduction of NaOH solutions into acid leachate

Table 1. Means and Ranges of Water Quality Parameters Measured monthly at McNabb Creek, Hemlock Creek, and Grassy Branch from April 1978 through March 1979.

Stream Site #	pH	Conductivity (µmhos)	Acidity*	Alkalinity*	Hardness*	Selected Heavy Metals Al (mg/1)	 Mn (mg/1)	 Fe (mg/1)
McNabb Creek (Station 8)								
04-05/78	4.8	60	19.8	2.0	26	**	**	**
07-12/78	6.4	88	8.1	7.3	20	0.2†	0.2†	0.1†
	(6.2-7.2)	(58-135)	(1.3-16.0)	(4.0-11.4)	(10-30)	(0.2-0.3)	(0.1-0.3)	(0.0-0.1)
01-03/79	4.8	66	13.0	-0.2	24	1.4	0.5	0.2
	(4.6-5.1)	(52-80)	(10.0-18.0)	(-0.5-0.3)	(12-32)	(0.9-1.7)	(0.4-0.5)	(0.0-0.4)
Hemlock Creek (Station 11)								
04-05/78	4.6	58	22.8	2.4	24	**	**	**
07-12/78	5.7	91	10.2	2.5	19	1.1†	0.8†	0.1†
	(5.5-6.2)	(57-140)	(0.8-19.9)	(-0.1-4.6)	(11-30)	(0.3-1.9)	(0.2-0.5)	(0.1-0.2)
01-03/79	4.9	61	12.0	0.0	25	1.8	0.3	0.2
	(4.7-5.0)	(51-70)	(8.0-17.0)	(-0.1-0.0)	(24-28)	(1.7-2.0)	(0.2-0.4)	(0.1-0.3)
Grassy Branch (Station 16)								
04-05/78	5.1	27	24.7	0.4	14	**	**	**
07-12/78	6.5	31	8.9	10.0	12	0.3†	0.2†	0.1†
	(5.9-7.0)	(19-62)	(2.4-12.2)	(0.2-15.0)	(3-28)	(0.3-0.4)	(0.1-0.3)	(0.0-0.1)
01-03/79	4.4	40	13.2	-0.8	13	0.7	0.5	0.1
	(4.3-4.7)	(30-46)	(8.6-21.2)	(-1.4-0)	(4-18)	(0.2-1.3)	(0.4-0.6)	(0.0-0.3)

05/78 - Mitigation measures began.
11/78 - Surface sealing of embankments completed.
01/79 - NaOH treatments terminated.

* (mg/l as $CaCO_3$)
** Not measured
† Measured 11/78 - 12/78

receiving streams created an additional problem in the form of yellowish-brown metal precipitate. Heavy floc accumulations that develop after water has been artificially restored (i.e. NaOH) have been found to severly limit zoobenthic communities (Herrics and Cairns 1974).

Table 2. Total Number and Weight (g) of fishes collected by electrofishing 200 ft (61 m) stream sections in the Citico/North River drainages from August 1978 through March 1979.

Stream (Site #) Species	Aug 78 No.	 Wt(g)	Dec 78 No.	 Wt(g)	March 79 No.	 Wt(g)
Sugar Cove (1)						
Rainbow trout (*Salmo gairdneri*)	11	142	12	212	3	122
Brook trout (*Salvelinus fontinalis*)	1	1[illegible]	1	23	2	57
aurel Branch (4)						
Rainbow trout	25	312	25	425	18	587
Blacknose dace (*Rhinichthys atratulus*)	12	67	18	68	12	66
Creek chub (*Semotilus atromaculatus*)	2	16	3	67	2	19
Northern hog sucker (*Hypentelium nigricans*)			2	232		
cNabb Creek (7)						
Rainbow trout	1	10	1	34		
Creek chub			2	23		
emlock Creek (10)						
ainbow trout	2	85				
Creek chub	3	40	2	13		
alls Branch (15)						
Brook trout	7	166	14	286	*	*
rassy Branch (16)						
"None"						
agle Branch (17)						
Rainbow trout	12	227	5	39	2	28
agle Branch (18)						
"None"						

Following completion of more permanent surface sealing of the road embankments and subsequent termination of NaOH treatments in January 1979, physical/chemical water quality parameters progressively degraded in comparison to reference sites. In-stream bioassays were conducted in March 1979 to evaluate the initial effectiveness of the permanent mitigation measures. In these 96 hr tests, acutely lethal conditions (100% mortalities) were observed at downstream sites in mitigated streams. During the same time period, no fish were collected by electrofishing sampling stations on McNabb Creek, Hemlock Creek, and Grassy Branch. From January through March 1979, pH levels of mitigated streams ranged from 4.3 to 5.3 and concentrations of Mn and Al approached 0.6 and 2.0 mg/1 respectively. These studies reveal that toxic materials were still entering streams 3 months after completion of the soil coverings. Additional time may be required for embankment stabilization and sealing processes to occur in mitigated Anakeesta road fill areas.

ACKNOWLEDGEMENTS

This project was supported by funds provided by the USDA Forest Service, Southeast Region, US Federal Highway Administration; Region 15 (administered by the Tennessee Department of Transportation), and Aquatic Ecology Fund, Environmental Biology Research Program, Tennessee Technological University. Assistance in typing and manuscript preparation by Joanne Arway is gratefully acknowledged.

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The Fishery Conservation and Management Act as a Tool for Mitigation in Outer Continental Shelf Petroleum Development[1]

Alison Rieser[2] and Judith Spiller[2]

Abstract. Georges Bank, on the Northwest Atlantic Continental Shelf, represents one of the world's most productive fisheries; yet, the adverse environmental effects associated with Outer Continental Shelf (OCS) petroleum development threaten this productivity. The potential for damage to fisheries stems from catastrophic events such as oil spills, pipeline breaches and well blowouts, but more certainly it comes from daily operational discharges and runoff drainage from drilling rigs and platforms. Such threats range from smothering, acute toxicity, uptake of heavy metals resulting potentially in physiological disruption, bioaccumulation and biomagnification to carcinogenicity and mutagenicity. Further, drilling activities often coincide with highly productive fishing areas and so preclude the use of these areas for fishing.

Current and proposed regulations applicable to OCS petroleum development inadequately protect critical fishery habitats on the Georges Bank. The Fishery Conservation and Management Act of 1976 (FCMA), through the regional Fishery Management Plans (FMP), provides a process for the definition and protection of these critical fishery habitats. On the Georges Bank, this operation involves the identification of spawning and prime grounds of species of concern and then the inclusion of these areas in the FMPs. Thus, by incorporating such critical areas into a FMP approved by the Secretary of Commerce, these areas would receive special consideration, so that the adverse effects of offshore development on fisheries would be minimized.

INTRODUCTION

Georges Bank, on the Northwest Atlantic Continental Shelf, represents one of the world's most productive fisheries (Hennemuth 1975); yet, the adverse environmental effects associated with Outer Continental Shelf (OCS) petroleum development threaten this productivity. The potential for damage to fisheries stems from catastrophic events such as oil spills, pipeline breaches and well blow-outs, but more certainly it comes from daily operational discharges and runoff drainage from drilling rigs and platforms. Such dangers range from smothering, acute toxicity, carcinogenicity, and mutagenicity to food chain effects resulting in bioaccumulation and biomagnification. Further, drilling activities often coincide with highly productive fishing areas and so preclude their use for that activity and outweigh any advantages that rigs serve as refugia.

Mitigation through existing regulatory authorities provides a method to minimize harm to a vital ecosystem such as Georges Bank. Unfortunately, the laws applicable to the OCS oil and gas process cover exploration, development and production and so do not provide a framework for environmental protection prior to the initiation of the OCS process. The Fishery Conservation and Management Act of 1976 (16 USC 1801 et seq.), however, through the employment of fishery management plans (FMPs), provides critical information on the fishery resource and presents the potential for the long term protection of sensitive habitats.

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[1] Paper presented at the Mitigation Symposium, Ft. Collins, Co., July 17-19, 1979.

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FISHERY MANAGEMENT PLANS

The Fishery Conservation and Management Act of 1976 (16 USC 1801 et seq.) established a comprehensive national program for the management of U.S. fisheries in the 200-mile Fishery Conservation Zone. Under the Act, responsibility for management of U.S. fishery resources is shared by the Secretary of Commerce and eight Regional Fishery Management Councils composed of state fishery officials and private individuals with experience in fisheries. The Regional Councils develop fishery management policies and strategies through a unique process of public participation. These policies and strategies are in turn implemented by Commerce's National Oceanic and Atmospheric Administration (50 CFR Parts 601-602) through regulations applicable to fishing operations. The key function of each Council is to prepare and submit Fishery Management Plans (FMPs) for important fish stocks under its jurisdiction. These FMPs can be an important link between Outer Continental Shelf (OCS) oil and gas operations and the protection of fishery resources in fishery-rich areas like Georges Bank. Information incorporated into these management documents on fish populations, ecological relationships, and the status of and threats to important habitat areas (50 CFR 602.3(b)) can provide the Secretary of Interior as well as other interested agencies and parties with information necessary to meet the Secretary's legal duty under the Outer Continental Shelf Lands Act (43 USC 1331 et seq., as amended by 43 USC 1801 et seq.) to protect fisheries from unreasonable harm from the exploration and development of OCS petroleum resources.

NOAA Guidelines for the development of FMPs require the Councils to provide a detailed description of the habitat of the stock or stocks of fish comprising the management unit. This description is to include factors affecting the habitat's productivity and its probable future condition, if its present condition and trends continue. The FMP must also describe the habitat areas which are of particular concern due to a requirement in the life cycle of the stock or stocks, for example, spawning grounds, nurseries, and migratory routes. Areas of concern which are currently or potentially threatened with destruction or degradation are to be described, as well as programs to protect or restore these habitat areas from destruction or degradation (50 CFR 602.3(b)(6)).

Once a FMP is approved by the Secretary of Commerce, the critical habitats defined in the plan should receive special attention from the Department of Interior in setting leasing schedules, selecting tracts for leasing, and developing environmental safeguards and regulations. State agencies can use the FMP information as a basis for their review of lessees' exploration plans under the consistency provision of the Coastal Zone Management Act of 1972 (16 USC 1456).

ENVIRONMENT OF GEORGES BANK

Georges Bank is a shallow extension of the Continental Shelf off southern New England (fig. 1). Its depth ranges from 2 to 100 fathoms (3.6 to 185 meters), and twelve thousand square miles of the Bank lie within the 100 fathom (180 meter) isobath with extensive areas of shoals (Wigley 1961). Water enters the Bank from the Gulf of Maine in the north and from the Slope Water Current which flows westward along the southern edge of Georges Bank. Currents on the Bank move in a clockwise gyre (Bigelow 1927, Bumpus 1976), and the gyre generally persists throughout the year (Vermersch and Beardsley 1977).

The clockwise gyre maintains Georges Bank as a distinct ecological unit. Currents passing over the shoals break down any incipient thermocline and mix overlying waters. Yentsch (1977) hypothesizes that the combination of mixing, depth of light penetration and the shallowness of the Bank maintain its high productivity. Mixing over the shoals releases nutrients to the surface from deeper waters. Because of the shallowness of Georges Bank, phytoplankton stay largely within the euphotic zone so that photosynthesis exceeds respiration. As a result, phytoplankton populations remain high year round.

The gyre also insures the high fishery yields by maintaining the eggs and larvae of the fish and shellfish which spawn over the Bank. This spawning activity takes place virtually year round (Bigelow & Schroeder 1953). Among the important commercial species which spawn on or near the Bank are haddock, cod, pollock, cusk, herring, yellowtail flounder, dab, gray sole, whiting, red hake, scallops and lobster (Colton & Temple 1961). All except herring have planktonic eggs and pelagic larvae.

The strength of the gyre varies on a yearly basis (Bumpus 1976, Bishop and Overland 1977). Some years it remains tight, and other years

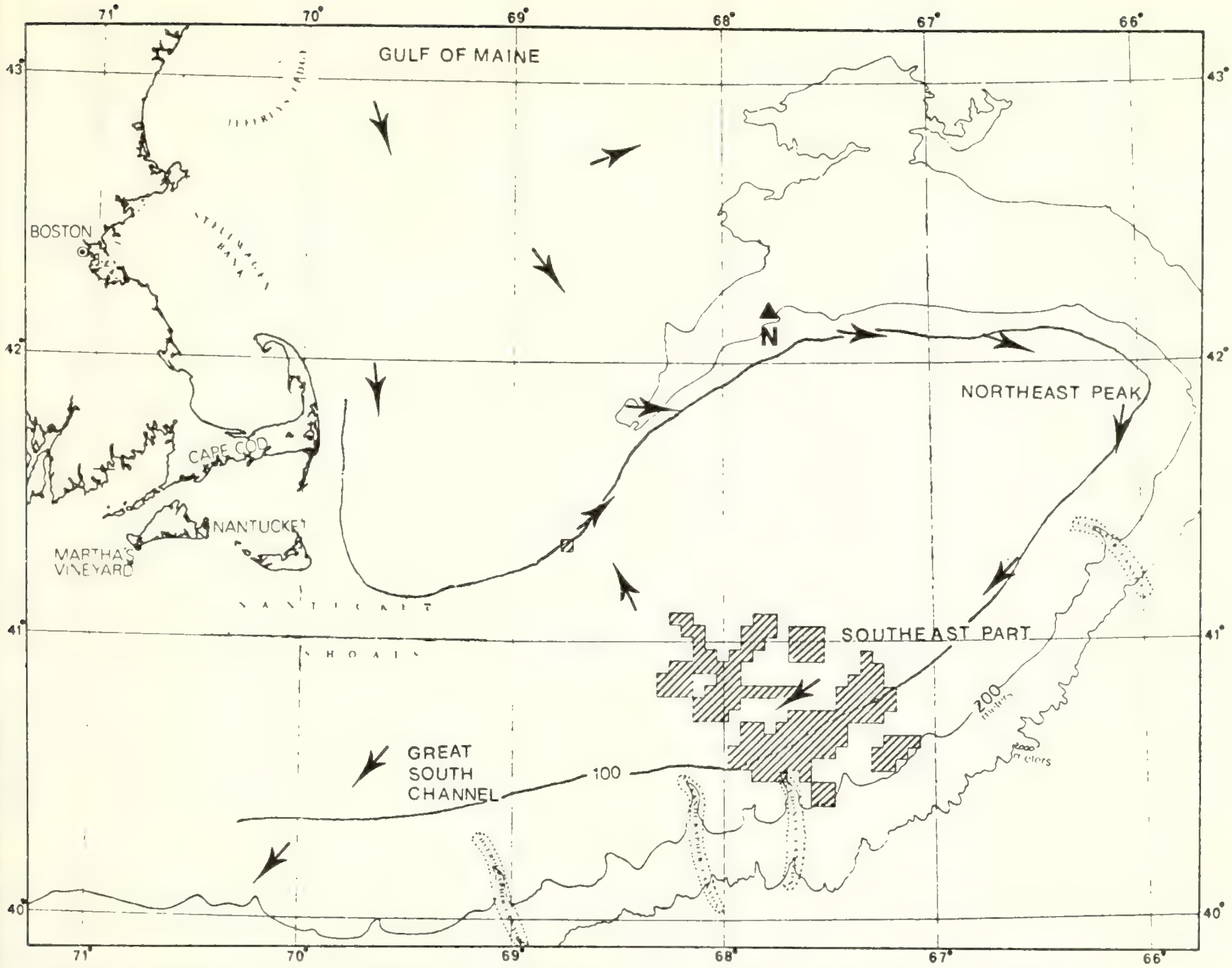

FIGURE 1 GEORGES BANK ▨ PROPOSED OCS SALE 42 TRACTS → SURFACE CURRENTS

it loosens probably serving as a mechanism for the dispersal of larvae, and potentially pollutants, to the mid-Atlantic. The average nature of the current regime, though, resupplies fish and shellfish to predictable areas of the Bank. The occasional breakdown of the system explains the more isolated occurrences of different species on the Bank and to the south. Unfortunately, the hydrographic features which insure the high productivity supporting the fisheries of Georges Bank also provide a mechanism for the entrapment of pollutants resulting from normal operating procedures and oil spills during OCS exploration and development.

THREATS FROM PETROLEUM ACTIVITIES

Threats to fisheries from OCS exploration and development arise from two sources: pollutants and use conflicts. Pollutants from normal operating procedures include drilling muds, cuttings, produced waters and deck drainage. Blowouts and tanker spills provide an unpredictable but large source of hydrocarbon contamination.

Drilling muds contain a variety of potentially toxic constituents ranging from heavy metals such as chromium to biocides such as pentachlorophenol (Montalvo & McKown 1975, Robichaux 1975). Bulk discharge of muds can result in smothering of benthic fauna and in clogging of gills of organisms. Discharge plumes also cause reductions in transmitted light resulting in localized decreases in photosynthesis (BLM 1977). This phenomenon affects phytoplankton populations and is potentially lethal to fish eggs and fish larvae. Further, fish in the Gulf of Mexico are attracted to releases of drilling discharges (N. Richards, pers. comm.). Grass shrimp show a similar response (Brannan & Rao 1979).

Drilling muds, produced waters (brines) and deck drainage are sources of heavy metals.

These metals include barium, cadmium, chromium, copper, lead, mercury, strontium and zinc (Rittenhouse et al. 1969, Montalvo & McKown 1975). Few of the field and monitoring studies of drilling operations have examined the uptake of metals by the local fauna. One which did, the Buccaneer oil field study (NOAA 1977), showed higher levels of heavy metals in fish, shrimp, barnacles and plankton than were present in the same species from the control site. The Gulf Universities Research Consortium (Montalvo & Brady 1975) did not find higher levels in its samples from oil rigs in Timbalier Bay, Louisiana; however, test and control localities were both in areas of petroleum production (Sanders & Jones, ms.).

Drilling discharges and deck drainage also contain hydrocarbons. Petroleum fractions, particularly polycyclic aromatic hydrocarbons, are carcinogenic and mutagenic (Freudenthal & Jones 1976). Further, fish eggs sampled from the area around the Argo Merchant oil spill had undergone a variety of mutations with effects ranging from mortality to developmental abnormalities (Longwell 1977). Lobsters exposed to hydrocarbons show alterations in behavior (Atema 1977) and a variety of physiological disruptions (Wells & Sprague 1976, Forns 1977).

Exposure to toxic discharges from OCS operations may also result in bioconcentration and food web transfer. The danger and degree of these effects for hydrocarbons remains unclear although some evidence of concentration, magnification and transfer does exist (Farrington 1977). The same situation exists for metals (Windom et al. 1973 a, b). Pentachlorophenol, however, is a dangerous and persistent pollutant (Rao 1978). Because fish and invertebrates are attracted to discharge plumes and mounds of drilling muds, their chance of exposure to hydrocarbons, metals and biocides is greatly increased and thus, the potential for biomagnification and transfer is increased, also.

The dangers of drilling discharges and hydrocarbons originating from these discharges, from deck drainage, and from blowouts and oil spills can be summarized as follows: 1. direct lethal toxicity, 2. sublethal effects such as disruption in behavior and physiology, 3. tainting of edible species, 4. bioconcentration and transfer of potentially carcinogenic and mutagenic polycyclic aromatic hydrocarbons and heavy metals, and 5. changes in biological habitats resulting in shifts in biological compositions. All of the above provide a potential for harm to the fishery resources. The degree to which they will in a frontier area is largely unknown. Thus, in areas of high productivity such as Georges Bank, petroleum operations must proceed with special caution, and the need for development must be weighed against the value of the resource.

Use conflicts on Georges Bank fall into two categories: physical obstructions to fishing and preemption of fishing grounds. Obstructions include debris lost during drilling operations and the navigational hazards presented by rigs, platforms, pipelines, subsea completions and service vessels. Emplacement of rigs, platforms, pipelines and subsea completions and their attendant safety zones preempt fishing areas. Several studies (URI 1976, WHOI 1976) estimate the fishing space removed due to oil and gas operations as minimal; however, when these operations take place in a limited area as is the case for Lease Sale #42 and if this area overlaps with prime fishing grounds, their probability of interfering with fishing greatly increases.

Fishing methods on Georges Bank often cover large areas (WHOI 1976). Trawling for haddock requires a high degree of maneuverability particularly during high seas. Long lining, another method used for haddock fishing, involves a bottom tending line which may be up to thirty-five miles long. Scallop dredges often dig 10-12 inches into the bottom and so can interfere or be damaged by pipelines. In lobster fishing, trapping lines are often a mile long with seventy to ninety traps attached.

Title IV, the Fishermen's Contingency Fund, of the OCS Lands Act Amendments of 1978, is described in the next section. Special protection of fishing operations, based upon information in the FMP could forestall such losses to fishermen. This protection could range from exclusion of oil and gas operations in prime grounds to requirements for special operating procedures.

EXISTING MITIGATION MEASURES

The Department of Interior, as the federal agency with lead responsibility for OCS petroleum development, is required under the National Environmental Policy Act (NEPA) (42 USC 4321 et seq.) to consider in its decision-making process prior to leasing areas of the OCS appropriate measures to mitigate the adverse environmental effects of such development (40 CFR 1502.14(f); 1502.16(h)). In addition, the OCS Lands Act Amendments of 1978 require the Secretary to minimize or eliminate any conflicts between OCS oil and gas exploitation and other uses of the marine environment, including fish and shellfish recovery (43 USC 1801, 1802). As discussed above, a significant environmental impact of OCS development on Georges Bank is the potential degradation or loss of fishery habitat that could occur as a result of acute oil spills, chronic low-level oil pollution, and the discharge of toxic materials in drilling muds and cuttings. A review of the Final and Supplemental Environmental Impact Statements on Lease Sale #42 (BLM 1977, 1979a), however, indicates that mitigation measures addressing these significant threats to fishery habitats of Georges Bank have not been designed taking into account valuable information from the regional fishery management process.

Oil spill contingency planning and an oil spill liability fund are designed to mitigate damages from oil spills resulting from OCS activities (BLM 1979a). Compensation to fishermen for damages to their vessels and gear caused by obstructions associated with oil and gas activities will be available under a Fishermen's Contingency Fund, to be administered by the National Marine Fisheries Service. For chronic discharges of oil and other toxic materials, the Secretary of Interior relies upon the enforcement of OCS operational controls and requirements imposed through special stipulations on oil and gas leases, OCS Operating Orders, and waste discharge permits issued by the Environmental Protection Agency (EPA) to reduce or prevent these sources of environmental degradation (BLM 1979a). The Supplement to the Environmental Impact Statement for Lease Sale #42 (BLM 1979a)indicates that the same measures relied upon to mitigate fish and fish habitat losses in OCS development in other parts of the U.S. will be employed to protect the fishery resources of Georges Bank. The enormous productivity of the Bank, however, seems to warrant application of mitigation measures that are designed specifically in light of the ongoing fishery management process for Atlantic groundfish, lobsters, scallops, herring, and other species.

For Lease Sale #42 oil company lessees may be required under special stipulations to their leases to conduct special environmental studies to determine the effects of their operations on significant biological populations or habitats in the leasing area. Based upon these studies, the U.S. Geological Survey of the Department of Interior may subsequently require modifications in their operations or other measures to protect these identified resources (BLM 1979a). In addition, drill cuttings and drilling muds from exploratory drilling on Georges Bank will either have to be disposed of by shunting through a downpipe to a depth of 20 to 30 feet below the ocean surface or by transporting to disposal sites approved by the Environmental Protection Agency (EPA) (BLM 1979a).

OCS Operating Order No. 7 will prohibit discharges of drilling muds, cuttings, sands, and other well solids containing free oil. It will also require compliance by operators of exploratory drilling ships, rigs, and platforms with effluent limitations and other conditions established by EPA (BLM 1979a) under the National Pollutant Discharge Elimination System (NPDES) of the Clean Water Act (33 USC 1751 et seq., Sec. 1332).

These mitigation measures have been relied upon for environmental protection of marine ecosystems in previous OCS leases by the Department of Interior such as the Baltimore Canyon in the mid-Atlantic. Other areas, for example the Tanner-Cortes Bank area off southern California (BLM 1979b) and the Flower Garden Banks in the Gulf of Mexico (NOAA 1979) enjoy tighter controls especially on drilling mud discharges. Data resulting from investigations of the effects of petroleum activities on the marine ecosystems do not provide assurance that these measures have been effective in protecting living resources (Rieser and Spiller, in prep.). Parties concerned about potential damage to the fisheries of Georges Bank have expressed considerable doubt as to the appropriateness of the traditional mitigation measures for the protection of the important food resource represented by Georges Bank (CLF 1979).

Early in 1978, the Secretary of Interior was enjoined from proceeding with the sale of Georges Bank leases by the Commonwealth of Massachusetts and the Conservation Law Foundation of New England on grounds that inadequate protection existed for the fishery resources of the Bank. The district court found that the Secretary has a legal duty under the OCS Lands Act, which is underscored by the Fishery Conservation and Management Act and NEPA, to see that oil and gas exploration and development is conducted without unreasonable risk to the fisheries. The Secretary had violated his duty by proceeding with Lease Sale #42 before passage of the major amendments to the OCS Lands Act, then pending in Congress, which would authorize environmental safeguards designed to protect fishery resources (Mass. v. Andrus 1978).

The U.S. Court of Appeals for the First Circuit agreed with the district court's finding in March of 1979, stating that the Secretary's legal duty "embraces a solemn responsibility to see that the great life systems of the ocean are not unreasonably jeopardized by activities undertaken to extract oil and gas from the seabed", even to the point of refusing to lease particular areas where the risks would be unreasonable. The preliminary injunction of the lease sale was lifted, however, because of the passage of the OCS Lands Act amendments (Mass. v. Andrus 1979).

The decision in the Georges Bank case raises the question of how the Secretary can assess whether particular oil and gas activities unreasonably jeopardize fisheries. Similarly, interested parties, including coastal states and the National Oceanic and Atmospheric Administration, must have a mechanism through which the Secretary's efforts to protect fishery resources can be evaluated. The fishery management planning process can provide both the information and public review mechanism made necessary by the Secretary's duty to protect fisheries. The following information on the fishery habitat resources of Georges Bank has been developed for the purpose of fishery management planning and is an example of fishery habitat information that could be valuable in designing mitigation measures for OCS operations.

CRITICAL FISHERY HABITATS

Three commercially important species on Georges Bank provide examples of the application of mitigating procedures to habitat protection under the fishery Conservation and Management Act. The species in question are 1) the haddock (Melanogramus aeglefinus), 2) the Atlantic sea scallop, (Placopecten magellanicus), and the 3) American lobster (Homarus americanus). Habitat protection in this process relies on the definition of critical life stages and then, for a given area such as Georges Bank, the correlation of these stages with specific geographic localities. Once the latter are delineated, they can be incorporated into the FMPs as we outlined above. The nature of the yearly revision of the FMP allows for the recognition of any natural shift in fish occurrences with time and so incorporates management flexibility.

We define critical life stages as 1) breeding, 2) spawning, 3) nursery and 4) adulthood. While these stages encompass the entire life span of the individual, their separation allows for the development of differing strategies of management and protection for each stage. Unfortunately, currently available fisheries data only allow for the designation of spawning areas and concentrations of commercially harvestable adults.

The important step in this process is the correlation of spawning grounds and adult or prime grounds with specific areas on Georges Bank allowing the designation of critical fishery habitats. The National Marine Fisheries Service collects data on fish occurrences from three sources: 1) reports filled out by fish processors on where the fish they have bought from fishermen have been caught; 2) interviews with cooperating fishermen provide another source of data; 3) The Fisheries Service also conducts surveys as part of their stock assessment program. These sometimes provide information on the critical stages cited above and on the exact location of the sampling. An additional source of data comes from informal interviews conducted with fishermen (URI 1976, Lanzillo 1978). This information, taken together, allows for the designation of specific areas of Georges Bank where spawning traditionally occurs and where adults usually aggregate.

Haddock

Two aspects of the haddock fishery make it an appropriate example for consideration here. The haddock stock is currently rebuilding after a period of severe overfishing. (Clark & Overholtz 1979). An oil spill occurring during the spawning time could result in the loss of one year class (BLM 1977) and so have a significant impact on the haddock fishery. Fish egg mortalities for cod and pollock were 25% and 46% respectively in the region of the Nantucket Shoals after the Argo Merchant oil spill in December of 1976 (U.S.D.C. 1977). Further, critical life habitats are identified in the fisheries management plan for haddock NERMC/NMFS 1977). During March through May the Plan prohibits fishing for demersal species on the Northeast Peak and Nantucket Shoals (fig.3) in order to protect spawning haddock.

Haddock populations on Georges Bank appear to be highly localized with little interchange between the stocks centered on the Northeast Peak, the Gulf of Maine - Nantucket Shoals and western Nova Scotia (Bigelow & Schroeder 1953, McCracken 1960, Halliday & McCracken 1970). Some fish migration does occur from Nantucket Shoals and Jeffreys Ledge across the Great South Channel (NERMC/NMFS 1977). Grosslein and Hennemuth (1973) found similarities among year classes from Maine, the Nantucket Shoals and the Georges Bank. They suggest either classes were responding to the same environmental parameters or that larval drift was taking place mixing some members of three stocks.

Haddock spawn on Georges Bank from January to June with peak spawning in March (Bigelow and Schroeder 1953). The distinct spawning grounds already referred to are the Northeast Peak and the Nantucket Shoals. The eggs, which are planktonic, drift for 13-15 days before hatching, and the resultant larvae are pelagic for 3-4 months until settlement (Bigelow & Schroeder 1953). During the pelagic phase, larvae feed on copepods (Blacker 1971). When they became demersal, they eat a variety of invertebrates.

The fish become mature at age 3 and since 1978 they recruit to the commercial fishery at the same age (NERMC/NMFS 1977). Because of the largely sedentary nature of the species, prime fishing grounds largely coincide with the prime spawning areas (fig.2,3). While these areas are outside the tracts posed for Lease Sale #42, and only the Nantucket Shoals stock coincides with sites for Lease Sale #52 they are not exempt from the effects of an oil spill because of the current regime. Further, eggs and larvae will travel through the discharges produced during oil and gas exploration and development. Thus, they are potentially exposed to the normal operating discharges associated with OCS operations.

Scallops

Scallop fishing on Georges Bank is concentrated on the Northern Edge, the Northeast Peak and the South Channel (fig. 2) (Posgay 1957, 1958). Sporadic beds occur on the Southeast Part and in other areas on the Bank reflecting the unpredictable nature of scallop settlement. The distribution of sea scallops is highly dependent on current patterns during the planktonic phase of the larvae (NERFMC 1978). The timing and location of the spatfall is largely dependent on the speed and direction of the local currents (NERFMC 1978). Thus, scallops may suddenly become abundant in one area with the bed representing one year class. Traditional scallop grounds then are maintained by average current regimes and the presence of the available settlement medium. Breakdowns in the current system during spawning times can result in the formation of isolated beds and in the dispersal of Georges Bank spawn to the mid-Atlantic.

Prime spawning grounds are coincident with prime scalloping grounds (URI 1976). Spawning in these beds usually occurs in September and October (Posgay and Norman 1958). The larvae are free swimming for four to six weeks, and settlement occurs in waters from 20 to 55 fathoms (36 to 90 meters) (Posgay and Norman 1958). Settlement has been observed on dead scallop shells (Caddy 1968), on other bivalve

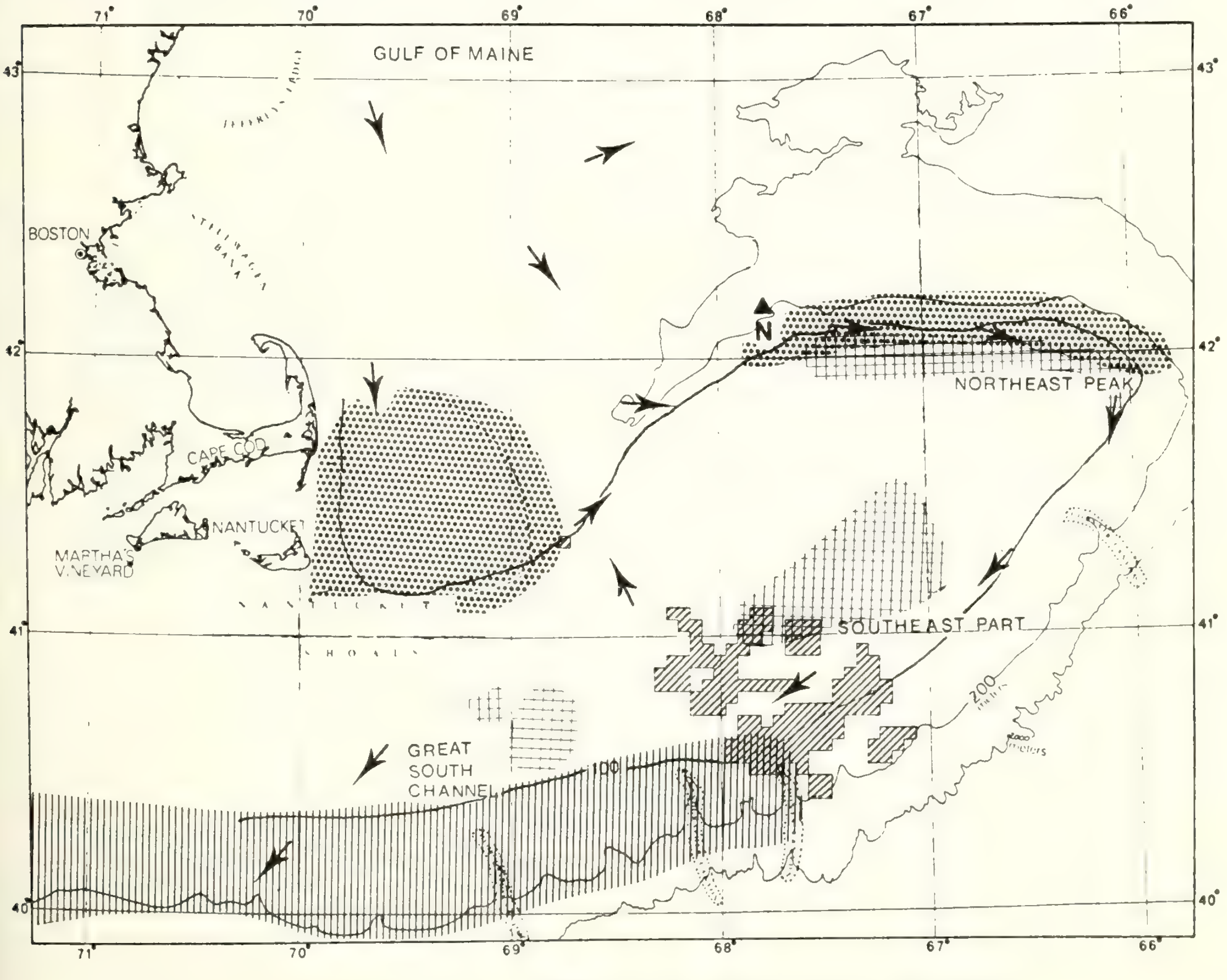

FIGURE 2 PRIME FISHING GROUNDS ▒ HADDOCK ╪ SCALLOPS ||||| LOBSTER

shells (Culliney 1974), and on bryozoans (Baird 1953). Maturation occurs at three years at which time scallops also become commercially harvestable (NERFMC 1978).

Adult scallops are free-swimming but highly localized in their distribution (NERFMC 1978). Scallops feed by drawing water containing dissolved food particles into their mantle cavities and across their gills (NERFMC 1978). Because they cannot escape burial, clogging in turbid waters often leads to smothering for scallops (MacKenzie and Merrill, In press). Stone (1974) found a significant decrease in filtering rates and weight loss when scallops were exposed to concentrations of 0.5 grams/liter of kaolin. Bryan (1973) found metal concentrations in kidneys and digestive glands of scallops highest during periods of lowest phytoplankton abundance when presumably rates of metabolism and excretion for the scallops were reduced.

Scallop populations on the Southeast Part of Georges Bank coincide with leases areas proposed for sale #42 (fig. 2). The westerly populations fall into areas under consideration for Lease Sale #52 (fig. 2). Because they are sedentary, adult scallops would be unable to escape drilling discharges if released on their beds. Shunting these discharges to the bottom or to 20 to 50 feet below the water surface, one method of disposal proposed in stipulation 4 for Lease #42 (BLM 1979a),would have the same effect on scallop beds. Thus, if drilling occurs in the vicinity of scallop beds, muds and other discharges should be barged elsewhere. Eggs and larvae of scallops from all regions on the Bank would be exposed to metals and hydrocarbons from drilling releases concentrated by the gyre. Finally, juvenile and adult scallops would inevitably feed on organisms contaminated by pollutants arising from drilling operations.

Lobster

The offshore lobster fishery in New England occurs on the edge of the Continental Shelf and in the heads of the Canyons bounding the southern edge of Georges Bank in waters from 40 to

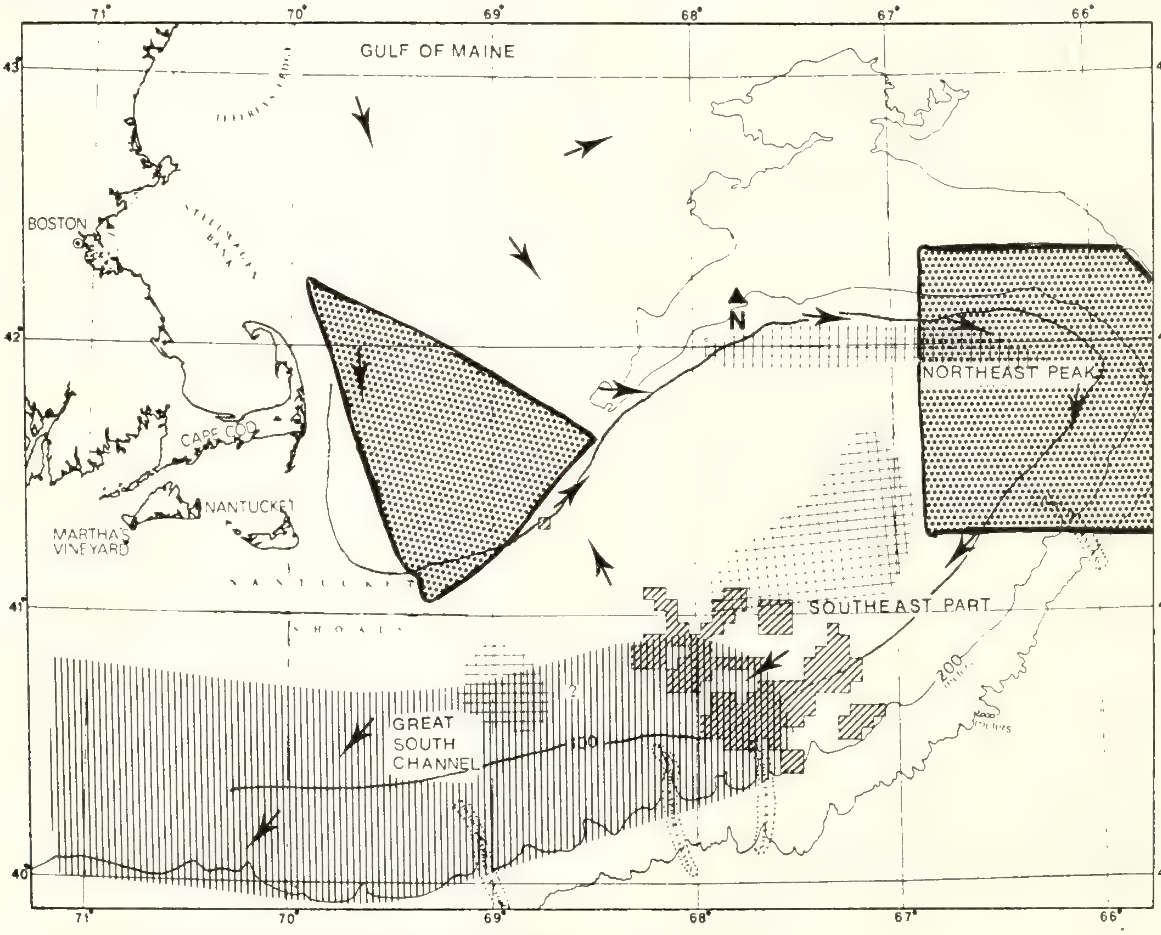

FIGURE 3 SPAWNING GROUNDS ▦HADDOCK ⊞SCALLOPS |||LOBSTER

Closed fishing areas outlined in black

180 fathoms (72 to 324 meters) (URI 1976, NMFB 1978, Burns & Clark ms.). Lease tracts proposed for Lease #42 coincide with part of this area (fig. 2) Unlike the examples provided by haddock and scallops, OCS oil and gas operations provide the greatest potential for direct damage to the lobster stock.

While many of the details of offshore lobster distributions are unknown (NMFB 1978), tagging studies indicate that offshore populations provide significant portions of inshore stocks. For example, Browns Bank supplies recruits for Nova Scotia (A. Stasko, talk presented in Boston, Ma. 1976). The central northeastern area of the Gulf of Maine plays a similar role for the coast of Maine (Thomas, pers. comm. cited in NMFB 1978). Further, at least 20% of the tagged lobsters released in the Long Island Sound and the Rhode Island Sound, respectively, moved offshore (Russell & Borden 1975). As for Georges Bank lobster, Uzmann et al (1977) found extensive shoalward movement of lobster in spring and summer with return to deeper waters in fall and winter. Fishing activity follows this trend (URI 1976). Thus prime grounds (fig. 2) shift from canyon heads to shoal areas to canyon heads from spring to summer to fall (Spiller and Linskey, in prep.)

Lobsters mate just after the female molts while her shell is still pliant (NMFB 1978). The male deposits a sperm packet on the underside of the female's carapace. If a second molt occurs, it results in shedding the sperm packet with the old exoskeleton. Peak spawning of Georges Bank lobster occurs from May to July (TRIGOM 1974, NFMB 1978). The resultant larvae are nektonic, feeding on the plankton for the two to five weeks they spend in the water column. Juvenile lobster appear to return to the area in which they were spawned (Morrissey 1975). Males mature at a length of about 70 mm and females from 50 to 70 mm (Morrissey 1975). Current regulations permit commercial harvesting of female lobster at a size below their level of maturity (NFMB 1978).

The potential for harm to the offshore lobster from OCS exploration and development, stems from polluting discharges and use conflicts. Because lobster spawning occurs in the late spring and early summer, and because lobsters migrate into shallower waters at that time, those lobsters from Lydonia and Gilbert Canyons could be spawning in areas of OCS activity. Preliminary bioassay data (Olesko-Szuts pers. comm.) indicate that used, whole drilling muds are toxic to adult lobsters at high exposures and disrupt behavior at lower levels. The dosages employed were within the ranges observed around drilling rigs in the Gulf of Mexico (Shinn 1974) and in southern California (Mearns and Moore 1976). Petroleum fractions also alter lobster breeding behavior (Atema and Stein 1974, Atema 1976, Atema et al. 1978), may accelerate ecdysis (Brannon & Rao 1979), and increase mortality among larval lobster (Wells & Sprague 1976, Forns 1977). Crude oil concentrations from 0.1 ppm to 1.0 ppm block chemoreceptors of adult lobster (Atema 1977) and affect the survival, development, metabolism and coloration of larval lobster (Forns 1977). Changes in coloration make larval lobster more susceptible to predation (Forns 1977). Further, drilling discharges can smother lobster during breeding periods. Shunting discharges would have this effect.

The nature of the circulation in submarine canyons (Stanley & Freeland 1978), BLM 1976 cited in BLM 1979) allows for the concentration of nutrients in the heads. Doubtless, this action provides an explanation for the concentration of juvenile and adult lobster in these regions. Pollutants, however, can also be concentrated by these mechanisms increasing the probability of the exposure of lobster populations to OCS discharges.

Like the larvae of haddock and scallops, once lobster larvae are in the gyre of Georges Bank they will be exposed to any heavy metals and petroleum fractions carried there also. No specific area can be designated to protect the species at this stage although strict discharge regulations can minimize levels of exposure.

Use conflicts involve the nature of trap fishing, the most common method of lobster capture (URI 1976). As discussed above, numerous traps are on one line. Service vessels traveling through the prime grounds during stormy weather could easily break such lines. If the line is broken, many lobsters are lost from the commercial market and from the breeding population. Further, rigs and platforms, particularly if they are concentrated in an area such as a canyon head, would preempt prime fishing grounds.

CONCLUSION

The fishery management planning process under the Fishery Conservation and Management Act of 1976 provides a mechanism for defining critical habitats for the major fish species. Strategies for the conservation and management of exploited fish stocks may involve restrictions on fishing operations in critical habitat areas during certain seasons. For offshore areas that are under consideration for oil and gas exploration and development, the same information which is useful for fishery management can serve to protect fishery resources from the adverse effects of petroleum operations.

Presently, several fishery management plans (FMPs) are either under development or are being implemented for important fisheries of Georges Bank. The Atlantic Groundfish FMP has established closed spawning grounds for haddock, indicating that for some species the identification of critical life stages can be used to ensure their continued productivity.

If future FMPs, for example for Atlantic scallops and American lobster, define critical habitats and the threats to their productivity posed by activities such as petroleum development, the traditional mitigation measures employed by federal agencies responsible for offshore activities can be improved. Shunting of waste drilling muds and drill cuttings will not protect lobster and scallop grounds from exposure to toxic materials. Further, special biological surveys to identify sensitive communities which are conducted during drilling operations may fail to prevent degradation of the habitats of these communities.

Restrictions which may be necessary to protect the Georges Bank fisheries include a ban on drilling in spawning and nursery areas and prime fishing grounds and a prohibition against all discharges from drilling operations on the entire Bank to minimize the concentration of pollutants by the gyre. FMPs for Georges Bank fisheries should require that these restrictions be imposed if petroleum activities are to occur.

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The Effect of Crested Wheatgrass Plantings on Wildlife on the Idaho National Engineering Laboratory Site[1]

Timothy D. Reynolds[2] and Charles H. Trost[3]

Abstract.--The species diversity and relative density of native vertebrates from habitats dominated by sagebrush and crested wheatgrass were determined and compared. The species diversity of nesting birds and large mammals, and the relative density of nesting birds, non-nesting birds, reptiles, and both large and small mammals were significantly lower in the crested wheatgrass plantings than in sagebrush habitats.

INTRODUCTION

Between 60 and 110 million ha of the western rangelands of the United States were once dominated by sagebrush, mostly big sagebrush (*Artemisia tridentata*) (Sturges 1973, Beetle 1960). Historically these lands were used primarily for livestock grazing, with range improvement practices directed towards increasing the forage material. Improvement practices typically involved the control and/or eradication of sagebrush and reseeding with grass species such as crested wheatgrass (*Agropyron cristatum* and *A. desetorum*). Braun et al. (1976) estimated that a minimum of 10% of the native sagebrush range had been altered since 1900. In Idaho, over 850 thousand ha of public and private land have been planted with crested wheatgrass.

In the past, research evaluating management practices on historic sagebrush rangeland had concentrated either on the response of livestock to improvement practices, or the impact of seedings on game animals. The objective of this study was to compare the species diversity and the relative density of native vertebrate populations (birds, mammals, and reptiles) in sagebrush and crested wheatgrass dominated habitats on the Idaho National Engineering Laboratory (INEL) Site.

MATERIALS AND METHODS

The INEL Site is a 2315 km^2 National Environmental Research Park located approximately 48 km west of Idaho Falls in southeastern Idaho. Four areas were selected for study. Two of these were dominated by big sagebrush, and 2 were former sagebrush ranges planted with crested wheatgrass nearly 20 years ago. The sagebrush study areas were separated by a distance of 12 km and each was adjacent to a crested wheatgrass study area. All information was collected in a 4 ha grid in each study area. The plant species composition and canopy coverage were sampled with 20 x 50 cm sampling frames (Daubenmire 1959) placed at 2.5m intervals along 4-100m transect lines in each grid system. For comparison purposes, native vertebrates were classified as: nesting birds (species actually nesting within the grids), non-nesting birds (migrants and those species nesting elsewhere), small mammals (ground squirrels and smaller), large mammals, and reptiles. Numbers of large mammals and both categories of birds were determined by visual observation. Small mammals were collected with snap traps concurrently in each area for 3 nights each month for 14 months. Traps were set in Calhoun Type-A trap lines (1959) and baited each morning with rolled oats and peanut butter. Reptiles were captured by hand or in pit fall traps placed at 50m intervals within the grids.

The relative density of each category of vertebrates was the number of individuals collected, captured, or observed (for small mammals, reptiles, and nesting birds respectively), and the total number of observations of large mammals and non-nesting birds. The Chi Square test (Zar 1974) ($p<0.05$) was used to evaluate the differences in relative density of the various categories. Species diversity (H) for each category was calculated using the formula:

$$H = \frac{n \log n - \Sigma f \log f}{n}$$

where f was the frequency of each species and n was the frequency of all species. Differences in species diversity were tested ($P<0.05$) using the t-test developed by Hutcheson (1970).

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RESULTS

Space does not permit a detailed description of the individual species responses to crested wheatgrass plantings. It is sufficient to say that only the western harvest mouse (Reithrodontomys megalotis) and the Horned Lark (Eremophila alpestris) had population densities in the crested wheatgrass areas that exceeded those in the sagebrush grids. On the other hand, 5 species of nesting birds were restricted to the sagebrush habitat. Tables 1 and 2 summarize the results of the relative density and species diversity comparisons respectively.

Table 1. RELATIVE DENSITY COMPARISONS

	RELATIVE DENSITY	
	SAGEBRUSH	CRESTED WHEATGRASS
NESTING BIRDS	57	14*
NON-NESTERS	417	189*
LARGE MAMMALS	127	78*
SMALL MAMMALS	346	202*
REPTILES	106	19*

*Significant

Table 2. SPECIES DIVERSITY (H) COMPARISONS

	SAGEBRUSH		CRESTED WHEATGRASS	
	# spp.	H	# spp.	H
VEGETATION	26	2.33	7	0.54*
NESTING BIRDS	9	1.62	4	1.05*
NON-NESTERS	35	2.33	23	2.15ns
LARGE MAMMALS	9	1.51	4	0.98*
SMALL MAMMALS	9	0.94	9	1.01ns
REPTILES	4	0.87	3	0.96ns

*Significant
ns Not Significant

CONCLUSIONS

The data indicate that, for the most part, converting native sagebrush rangeland to a crested wheatgrass monoculture has a negative effect on native wildlife populations. The reduction in plant species diversity in the crested wheatgrass plantings was accompanied by a reduction in the species diversity of both nesting birds and large mammals using that habitat. Additionally, the relative density of all groups of vertebrates examined was significantly lower in the crested wheatgrass plantings, indicating that from the standpoint of wildlife use these habitats are inferior to the native sagebrush dominated range. Mitigation alternatives for sagebrush conversion projects were not germane to this study. Nor was the study a condemnation of past land use practices. Rather, this study was a documentation of the impacts of crested wheatgrass plantings on wildlife. With the current enthusiasm for coal strip mining in the west, and the proposed reclamation of tailings with crested wheatgrass, it is vital that land and habitat managers be aware of the impacts of these plantings on wildlife.

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Mitigation of Estuarine Fisheries Nurseries: Seagrass Restoration[1]

Anitra Thorhaug[2]

Abstract.--Thousands of square miles of fisheries nurseries have been destroyed by man's activities in estuaries. A new method of seeding the dominant subtropical and tropical seagrass Thalassia in large-scale submerged restoration efforts demonstrates rapid regrowth (4-5 years), large animal population recolonization, and cost-effectiveness over plugging.

Prior to NEPA (1969) man's impact in the U.S. estuaries was extremely extensive: dredging, filling, dumping of effluents, waterfront siting of industrial and private sectors, canals, channels, ports, airports and military installations. There are now thousands of square miles of formerly prime fisheries nurseries lying barren in the coastal zone due to the above impact. Frequently the dominant vegetation impacted is seagrass, slow-growing intertidal and submerged species which bind the sediment and serve as food and habitat for juvenile fisheries animals. With the new federal and in some cases, state and local restrictions, mitigation for damage to seagrass beds is being required. Several recent symposia summarizing these efforts (Thorhaug, 1977; Thorhaug and Austin, 1976; Thorhaug, in press) have been held.

A series of large-scale seagrass mitigation projects, chiefly by planting Thalassia seedlings, was successfully accomplished in Biscayne Bay, Florida, a subtropical estuary on the lower east Atlantic seaboard. The results are expected to be extrapolated to parts of the Gulf of Mexico, southeast Atlantic coast, and Caribbean, where the species Thalassia dominates and Halodule wrightii is a successional or intertidal species.

At a power plant in Biscayne Bay approximately 25 acres of Thalassia had been denuded to bare sediment by effluents (diverted permanently to offstream cooling at the time of restoration). In this pilot effort, more than 6000 Thalassia testudinum seedlings were planted at various intervals in two corridors 150 m x 6 m. Five years later, the restored specimens had flowered and fruited so that adjacent areas were receiving seedlings. The restored specimens had also reached abundances and biomass levels of "natural" control areas not impacted by thermal effluents (Thorhaug, 1979). Fisheries organisms such as pink shrimp and juvenile fishes were statistically significantly different between restored areas and areas remaining denuded. No statistical difference occurred between "control" animal populations and the restored ones. This effort was funded by the U.S. Department of Energy and Florida Power and Light Company.

Several more large-scale seagrass mitigation efforts were carried out very recently (summer, 1978); preliminary results are available. The northern part of Biscayne Bay has been severely and multiply impacted since 1896, although recently much of the pollution effluent has been removed. Denudation of seagrasses, turbidity from bottom suspension, and alteration to circulation remain. Two plots, totaling approximately 10 acres, were planted with more than 80,000 seedlings of Thalassia as mitigation for two dredging projects (Port of Miami and Miami-Dade Water and Sewer Authority). One recipient site had been dredged and filled twenty years previously with no recolonization of Thalassia. A second site had been severely impacted by sewage, oil and dredging and filling. Water quality on certain tides was still turbid due to uncompacted sediment. Plants after nine months averaged 4.4 blades of 11.6 cm and 7.0 roots of 7.4 cm in length. 51% had rhizomes. This compared favorably to the growth rate at the power plant mitigation (described above) although the general water quality was thought to be less in the latter area.

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[1] Poster presented at the Mitigation Conference, Fort Collins, Colorado, July 17, 1979.

[2] Courtesy Professor, Department of Biological Sciences, Florida International University, Miami, FL 33199.

Table 1.--Seedling growth, eight months.

	36th Street Causeway	Margaret Pace Park	North Biscayne Bay (Mean)	Turkey Point
Number of Blades	4.58	3.88	4.39 ± 0.93	3.7
Longest Blade in cm	11.54	11.92	11.62 ± 2.40	16.50± 4.0
Number of Roots	6.36	9.00	7.02 ± 1.95	8.6 ± 2.6
Longest Root in cm	7.41	7.88	7.36 ± 1.91	6.8 ± 2.8
Length of Rhizome in cm	1.50	0.99	1.37 ± 1.88	4.7 ± 2.5
% Rhizome	53[1]	42%	51%	89%

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[1] Short shoot apparent in approximately 10% of population.

The fisheries organisms which recolonize the submerged Thalassia beds four years after planting have been studied and several reports are available (McLaughlin and Thorhaug, 1978; McLaughlin and Thorhaug, 1978a; McLaughlin *et al*., in press). The major fisheries results are seen in the following data from McLaughlin *et al*. (in press) from replicate trawls.

Clearly the restored Thalassia bed studied by McLaughlin *et al*. (in press) has a high abundance of fisheries species within four years of planting which is not significantly different from control (impacted) animal populations (as explicated in detail by Thorhaug and Roessler, 1977). The rapid recolonization of the animal community has been observed in the north Biscayne Bay sites, but has not been investigated in quantitative detail. An adjacent power plant several miles north of Turkey Point, after being closed due to age, had extremely few observed organisms in the area of denudation and extremely few recruits of Thalassia.

Table 2.--Average abundance of selected animals collected per trawl versus vegetation types at a four-year restored seagrass site.

	Barren Unrestored	Restored Thalassia	Control (Unaffected) Thalassia
JULY			
Crustacea	3	432	[1]
Penaeus	1	24	[1]
Fishes (juvenile)	7	37	[1]
OCTOBER			
Crustacea	6	575	532
Penaeus	8	132	5
Fishes (juvenile)	10	164	44
JANUARY			
Crustacea	1	80	295
Penaeus	0	5	2
Fishes (juvenile)	2	43	23
APRIL			
Crustacea	0	61	108
Penaeus	0	2	3
Fishes (juvenile)	0	107	24

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[1] No samples taken in July.

The successful regrowth of the Thalassia populations from this method of restoration and under several severely impacted situations has led us to extrapolate this technique to be useful for mitigation of a series of impacts such as dredging, artificial island or causeway submerged stabilization, and restoration after pollutants have been removed.

ACKNOWLEDGEMENTS

The restoration at Turkey Point was funded by a DOE grant with matching money from Florida Power and Light Company. The north Biscayne Bay exploratory investigation study was funded by Sea Grant. The Margaret Pace Park and 36th Street Causeway planting was funded by the Port of Miami and the Miami-Dade Water and Sewer Authority.

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☆ U.S. GOVERNMENT PRINTING OFFICE 1979 - 681-282/71 Reg. 8

Swanson, Gustav A., tech. coord. 1979. The mitigation symposium: a national workshop on mitigating losses of fish and wildlife habitats. July 16-20, 1979, Fort Collins, Colo. General Technical Report RM-65, 696 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Nine private organizations and eight federal agencies cosponsored the symposium, which consisted of 133 papers presented in three concurrent sesssions (and a poster session) on: coastal zone wetlands; inland wetlands; economic considerations; mining, oil, and gas; planning, evaluation, and inventory; surveys; power projects; terrestrial management; aquatic management; legal and political considerations; transportation systems; and state perspectives.